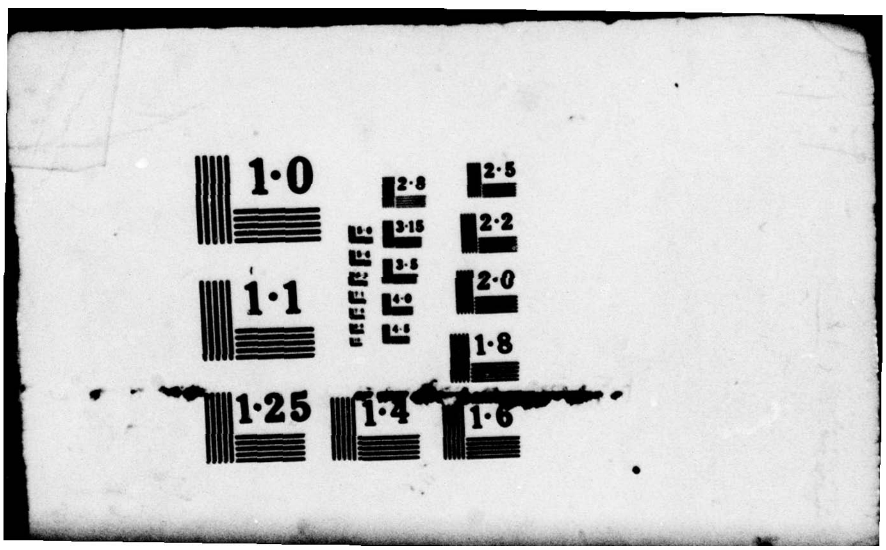
AD-A072 318 CANYON RESEARCH GROUP INC WESTLAKE VILLAGE CALIF F/G 5/9
DESIGN REQUIREMENTS FOR AN AUTOMATED PERFORMANCE MEASUREMENT AN--ETC(U)
JUN 79 R T HENNESSY, S F BARNEBEY DAHC19-77-C-0008
UNCLASSIFIED FTR-02-78 ARI-RR-1220 NL

1 OF 2
AD
A072318


1·0
2·8
2·5
3·15
2·2
1·1
3·5
2·0
4·0
4·5
1·8
1·25
1·4
1·6

Research Report 1220

DESIGN REQUIREMENTS FOR AN AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM FOR THE UH-1 FLIGHT SIMULATOR

Robert T. Hennessy, Roik L. Hockenberger,
Steve F. Barnebey, and Donald Vreuls
Canyon Research Group, Inc.

ARI FIELD UNIT AT FORT RUCKER, ALABAMA

ari

U. S. Army
Research Institute for the Behavioral and Social Sciences

June 1979

Approved for public release; distribution unlimited.

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

JOSEPH ZEIDNER
Technical Director

WILLIAM L. HAUSER
Colonel, US Army
Commander

NOTICES

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Research Report 1220	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	9
4. TITLE (and Subtitle): 6 DESIGN REQUIREMENTS FOR AN AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM FOR THE UH-1 FLIGHT SIMULATOR,	5. TYPE OF REPORT & PERIOD COVERED: Final Report. 19 Jul - 14 Nov 77
	6. PERFORMING ORG. REPORT NUMBER: FtR-02-78
7. AUTHOR(s): 10 Robert T./Hennessy, Steve F./Barnebey, Roik L./Hockenberger, Donald/Vreuls	8. CONTRACT OR GRANT NUMBER(s): 15 DAHC19-77-C-0008
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Canyon Research Group, Inc. 741 Lakefield Road, Suite B Westlake Village, CA 91361	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 16 2Q263743A772
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Aviation Center Fort Rucker, Alabama 36362	12. REPORT DATE: 11 June 1979
	13. NUMBER OF PAGES: 125
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, Virginia 22333	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

12 138p.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

14 FTR-Ø2-78

18. SUPPLEMENTARY NOTES

18 ARI 19 RR-122Ø

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Automated performance assessment
Instrument flight training
Performance measurement
Measurement
UH1FS training
Flight simulator training
Helicopter flight training

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the development of an automated performance measurement and grading system for instrument flight training in UH-1 flight simulators (UH1FS). A survey and analysis was conducted of the hardware and software architecture of the UH1FS and the Basic and Advanced Instrument maneuver profiles used for instrument flight training. Design requirements were developed for an automated performance measurement system which produces a composite maneuver grade and diagnostic error messages. The system is

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

391 185 Gm

20. continued

based on final criteria referenced performance and measurement of the aircraft variables which are the critical indicators of performance. An estimate of the maximum and minimum data collection requirements for utility and acceptance testing of the system is included.

Research Report 1220

DESIGN REQUIREMENTS FOR AN AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM FOR THE UH-1 FLIGHT SIMULATOR

Robert T. Hennessy, Roik L. Hockenberger,
Steve F. Barnebey, and Donald Vreuls
Canyon Research Group, Inc.

Submitted by:
Charles A. Gainer, Chief
ARI FIELD UNIT AT FORT RUCKER, ALABAMA

Approved by:

Frank J. Harris, Acting Director
ORGANIZATIONS AND SYSTEMS
RESEARCH LABORATORY

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

June 1979

Army Project Number
2Q263743A772

Aircrew Performance
and Simulation

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Army Research Institute Field Unit at Fort Rucker, Alabama, has the mission of providing timely research and development support in aircrew training for the U. S. Army Aviation Center. Research and development is conducted in-house, augmented by contract research as required. This research report documents contract work performed as a part of the Field Unit's Flight Simulation Task.

The entire program of aviation training research and development is responsive to the requirements of RDT&E Project 2Q263774A772, Aircrew Performance Enhancement in the Tactical Environment, and to the U.S. Army Aviation Center, Fort Rucker, Alabama.

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the following individuals for their invaluable contributions to the project.

Dr. James A. Bynum, Technical Team Manager, US Army Research Institute Field Unit, offered useful and thoughtful comment and discussion.

Messrs. Bobby W. Hogan and Edward J. Benak, DAC Instructor Pilots, Department of Flight Training, USAAVNC, reviewed maneuver segmentation, requirements, common errors, measures and tolerances.

Chief Warrant Officer 2 Charles E. Carr and Mr. Hans D. Langhammer, Pilots, Army Research Institute Field Unit, expertly flew maneuvers in the UH1FS and provided useful input to the maneuver analyses.

Major William C. White, Jr., Research and Development Coordinator, US Army Research Institute Field Unit, provided research coordination and assisted in flying the maneuvers in the UH1FS.

Dr. George E. Long, Technical Director, Canyon Research Group, Inc., provided guidance and offered many valuable suggestions during the course of the project.

EXECUTIVE SUMMARY

The purpose of the project was to design an automated performance measurement and grading system for instrument flight in UH-1 flight simulators (UH1FS). A survey and analysis was conducted of the hardware and software architecture of the UH1FS and the Basic and Advanced Instrument profiles used for instrument flight training. This was followed by the development of the design requirements for an automated performance measurement system which produces a composite maneuver grade and diagnostic error messages. Software implementation design requirements also were produced. The following is a summary of the work performed and the key characteristics of the automated performance measurement and grading system.

REQUIREMENTS

Three major requirements were stated for the work: (1) the measurement system must be capable of implementation in the UH1FS without additional hardware and with minimum changes to the existing software; (2) a minimum number of measures were to be used consistent with providing a grade and diagnostics; and (3) the performance measurement system was to be designed for use with the automated Basic and Advanced Instrument maneuvers implemented in the UH1FS.

WORK TASKS PERFORMED

Review

Flight performance measurement systems in general, Initial Entry Rotary Wing (IERW) instrument training curricula, required performance criteria, and the current flight grading system were reviewed. The maneuvers themselves were reviewed principally by flying through the maneuver several times and examining the auto-briefing voice transcripts.

Maneuver Analysis

One Basic Instrument and five Advanced Instrument maneuvers were selected for subjects of the performance measurement system. These maneuvers are: (1) Climbing and Descending Turns; (2) NDB Approach; (3) VOR Approach; (4) ILS Approach; (5) Localizer Backcourse Approach; and (6) Holding at Intersection. By analysis, each maneuver was divided into several segments based on selecting distinctive points in the maneuver profile where the performance requirements changed significantly. In consultation with subject matter experts (SMEs), the performance requirements and common errors for each segment were determined. These served as the basis for development of the performance measures.

Performance Measurement Development

Performance measures, and associated start-stop logic conditions for measurement, were developed for each of the six maneuvers. The candidate measures and the start-stop logic conditions were then reduced and consolidated to a common group which were applicable to the six maneuvers.

UH1FS Control Architecture and Analysis

Concurrent with the above tasks, analysis of the UH1FS control hardware and software was conducted to gain a working knowledge of the simulation system and its capabilities and limitations relevant to the implementation of the measurement system.

Grading and Diagnostic System

The grading procedure and diagnostics for the maneuvers were produced. The principal goal of the grading and diagnostic system development was to make the grades and diagnostics meaningful and easily understood by students and rated pilots.

Acceptance Test and Utility Test Plans

The final task was to develop an implementation test plan and a plan for testing the utility (validity and reliability) of the measurement and grading system. The acceptance test defines procedures for demonstrating that the performance measurement system was implemented according to the design. Utility testing insures that the system, in fact, measures the ability of a pilot to fly instrument maneuvers.

PERFORMANCE GRADING AND MEASUREMENT SYSTEM

Performance Measurement

Twenty-two measures were developed which could be applied to the six selected maneuvers. The measures fall into three general categories: (1) aircraft control; (2) navigation; (3) radio procedures.

Four key features characterize the measure set. First, the variables measured are the aircraft referenced critical variables of instrument flight. The variables are critical because there is a specific requirement for them to be maintained at a desired value (which may change) throughout the maneuver. Some examples of the variables and the consequent measures are: airspeed, trim, altitude, heading, turn rate, VOR tracking, glideslope tracking, and transmission of radio calls at the proper time. Second, the performance criteria values for the measures are based on the final criteria for performance expected from a rated Army aviator. Third, three criteria or tolerance levels were defined for each measure which nominally correspond to good, average, and poor performance. The second tolerance level divided performance between satisfactory and unsatisfactory as defined by relevant Army regulations, or in the absence of published criteria, the consensual opinion of pilot SMEs. Fourth, a performance error is not registered unless one of the three tolerance levels are exceeded for a specified number of seconds. Thus, error detection occurs in a manner comparable to that which a pilot detects errors by reference to his flight instruments; i.e., transient tolerance violations, promptly corrected, are not considered performance errors.

Start-stop logic conditions, which determine when a measure will start and end, were developed concurrently with the measures. If a start-stop logic condition is not met or the performance of the pilot is extremely poor, measurement may be erroneous. To safeguard against this possibility, a set of conditions, called fatal errors, were defined to terminate measurement if violated.

Grading and Diagnostics

The grading system produces a single composite score reflecting the pilot's overall performance on each of the maneuvers. The maneuver score will be of use to training managers and allow the pilot to compare his performance to that of others or his own past performance.

The key characteristic of the grading system, which is a reflection of the performance measurement technique, is that the score is based on absolute criteria so that no account is taken of the pilot's past experience or amount of training received.

The recommended format for the grading system is a six-point numerical scale ranging from 1 to 6. A score of 1 indicates the worst performance level, and a score of 6 indicates the best performance level. Grades within the range of 1 to 3 are considered to reflect degrees of overall unsatisfactory performance, and grades in the range of 4 to 6 are considered to reflect degrees of satisfactory performance. This grading system is compatible with one developed concurrently for inflight performance assessment.

In addition to providing composite maneuver grades, the system will produce diagnostic error messages to tell the pilot in clear text the type of error made and the tolerance level exceeded. A single diagnostic error message is associated with each of the 22 measures used to assess performance.

The output for the automated performance measurement and grading system is a printed page that contains (1) header information identifying the pilot, the date, and the maneuver flown; (2) the maneuver score; and (3) the diagnostic error messages for each segment of the maneuver.

IMPLEMENTATION

Software implementation design requirements were produced for the measurement and grading system. It was possible to formulate an implementation design that is heavily reliant on using single bits (binary digits) to encode various information elements about the measures, start-stop logic, criteria and errors committed. The recommended design is extremely compact and is implementable in a UHIFS without additional hardware and with only minor changes in the control software.

INTRODUCTION

This project was performed under Contract DAHC19-77-C-0008, sponsored by the US Army Research Institute for the Behavioral and Social Sciences. The purpose was to develop and design implementation requirements for an automated performance measurement and grading system for use in the UH-1 Flight Simulator (UH1FS).

The performance measurement and grading system described in this report will be useful in many ways. It will provide objective performance data for Army Flight Training Management and training research. It will provide diagnostic information to the student pilot and his instructor pilot (IP). The amount of IP time now necessary for evaluation will be reduced and, consequently, IPs will be able to devote more time to training.

This report has four chapters. The first chapter is background on the UH1FS and the approach taken to develop the performance measurement and grading system design. The second chapter describes the development of the system design. The third chapter is a general description of the UH1FS computer control system and the design requirements for the implementation software. The fourth chapter is a description of test plans, a statement of requirements for a user handbook, and expansion of the system to other maneuvers. General conclusions end the chapter. The specific measurement requirements for six UH1FS instrument maneuvers are presented in the appendix.

CHAPTER I

UH1FS BACKGROUND AND SUMMARY OF APPROACH

UH-1 FLIGHT SIMULATOR

PHYSICAL ORGANIZATION

The UH1FS (Device 2B24) consists of four cockpits, each mounted on its own five-degree of freedom motion base controlled by a single computer system. The appearance and function of cockpit instruments and controls are identical to the UH-1 helicopter. Currently, the UH1FS is used only for instrument training and has no external visual system.

Simulated flight can occur within a 100 x 100 mile gaming area which, at Fort Rucker, is roughly a representation of Southern Alabama and parts of the adjacent states. All radio navigational aids which exist in the represented area are included in the simulation.

UH1FS INSTRUMENT FLIGHT TRAINING

The UH1FS may be used in any of three modes, semi-automatic (SEMI-AUTO), automatic (AUTO), and checkride (CK-RIDE). In the SEMI-AUTO mode, the aircraft initially can be placed in any location and altitude within the gaming area. Using the flight instruments and radio navigational aids, the aircraft can then be flown anywhere within the gaming area and make instrument approaches to several airfields. In the AUTO mode, one of ten preprogrammed instrument flight maneuvers can be selected for demonstration or practice. Computer controlled voice tapes provide a briefing on the flight profile, describe demonstrated maneuvers as they are flown, and alert the pilot to check various flight instruments during practice. In the CK-RIDE mode, the pilot flies a long cross-country trip. There are no voice alerts, but basic variables of flight such as altitude, airspeed, etc. are recorded for printout at the end of the practice session.

FEEDBACK AND GRADING

A student pilot receives performance feedback from, and is graded by, his IP. The same procedures are used in the UH1FS as are used in the real aircraft. As an aid to the student and the IP, CRT displays are located both in the rear of the cockpit and at the simulator control console. The displays present a time history of the aircraft ground track, airspeed and altitude. It is therefore possible for a pilot to review some aspects of his performance after completion of an instrument maneuver.

In addition to the CRT display performance information is available on a teletype printer. Average aircraft state data such as airspeed, trim, heading, etc., can be printed for the entire maneuver. The same information can be printed as a bar graph for a group of students. This information, however, is difficult to interpret in a meaningful way and is rarely referred to by either student pilots or their IPs. The lack of an adequate automated performance measurement system for the UH1FS is the primary reason for the present work.

APPROACH

This section describes requirements given for the design of the UH1FS automated performance measurement and grading system, the principal working assumptions which guided the development work and the work steps performed.

REQUIREMENTS

The stated requirements for the automated performance measurement and grading system are:

1. The system must be specifically applicable to the preplanned UH1FS instrument maneuvers available in the AUTO mode.

2. The system must provide a single, composite maneuver grade score for use by training managers.

3. The system must be able to operate within the existing UH1FS hardware and software structure.

4. The system should produce diagnostic information which is meaningful to pilots and is clearly presented.

WORKING ASSUMPTIONS

This section describes the basic working assumptions about flight performance measurement that significantly affect the character of the automated performance measurement and grading system.

Final Criterion Based Assessment

The primary assumption for the automated performance measurement and grading system is that instrument flight performance should be assessed by reference to explicit, public, minimum performance criteria that must be met to be a qualified Army aviator. In other words, the quality of instrument flight performance is indicated by the pilot's ability to control the aircraft, navigate, and perform procedures in the manner and to the degree specified by Army regulations.

The grade received by a student pilot in Initial Entry Rotary Wing (IERW) training will reveal the difference between his current instrument flight performance and the expected final performance criteria. Under the present grading system, the amount of training received by a student pilot is subjectively taken into account by the IP assigning the grade and, therefore, no indication of progress is possible.

Use of Critical Aircraft State Variables for Measurement

Performance criteria are defined in terms of aircraft state variables and not pilot behavior. In instrument flight, the pilot is required to maintain specific aircraft variables such as altitude, heading, airspeed, etc., at some desired value. Measures of pilot behavior such as control movements or visual scanning of the instruments may be important for training diagnosis, but they do not directly reveal the ability of the pilot to control the aircraft. All measures used in the present system are therefore aircraft referenced and only those variables are measured which relate directly to the performance criteria.

Use of Tolerance Limits for Error Definition

Criterion for each aircraft state variable consists of two parts, a desired value and an error tolerance. That is, a pilot cannot maintain a variable such as altitude without the slightest deviation from the desired value. It is not sufficient, however, simply to measure the deviation from the desired value because knowing the deviation is not the same as knowing that the variable was always within or exceeded some limit which divides acceptable and unacceptable performance. For the present system, it was decided that up to three tolerance limits around the desired value would be specified for each measured variable. By using multiple tolerance levels, it can be determined not only that performance was acceptable or unacceptable, but also information on the severity of the error is provided. Defining error in terms of tolerance levels also has the advantage of conceptual simplicity and allows a very efficient implementation.

Validity of Subject Matter Expert (SME) Opinion

The last working assumption is that the consensual opinion of the SMEs such as standardization instructor pilots and instrument instructor pilots is a valid source of information for instrument flight performance requirements and criteria when published criteria are absent. Throughout the course of this work, SMEs have been used for this purpose.

TECHNICAL APPROACH

Development of the automated performance measurement system design involved several work steps. The products of these are described in the succeeding chapters. This section outlines the project task requirements and the technical approach to them.

Review

The first task was information gathering on performance measurement, IERW instrument training curricula, the Basic and Advanced Instrument maneuvers in the UH1FS, the current inflight and UH1FS grading systems and published criteria of performance.

Information on flight performance measurement was gathered by review of the IERW instrument training curricula, the flight grading system, and the performance criteria were gathered primarily by review of several documents and consultations with SMEs.[1,2,3,4,5,6]

The automated Basic and Advanced Instrument maneuvers implemented in the UH1FS were reviewed primarily by flying through the maneuvers several times, examining the voice tape transcripts and consultation with UH1FS facility personnel. A minor amount of information on the UH1FS and the automated instrument maneuvers is contained in the Rotary Wing Instrument Guide[7] and the UH-1 Flight Simulator Handbook.[8]

Candidate Measure Development

Candidate measures were developed for each of the selected Basic and Advanced Instrument maneuvers. Each maneuver was considered individually without reference to the measures selected for the other maneuvers. All the individual measures were then consolidated to a common group. The measure selection was based primarily on the performance requirements developed during the maneuver analysis and the critical variables of interest in each segment of each. The characteristics of the measures are discussed fully in the appendix.

Preliminary Grading and Diagnostics Development

Once the candidate measure set had been developed, attention was given to the nature and format of the grading and diagnostics which would be produced by the system. This effort was considered preliminary because its primary purpose was to determine the approximate scope of the implementation requirements for the desired output.

UH1FS Hardware and Software Analysis

Concurrently with the first three tasks, an analysis of the UH1FS hardware and software architecture was conducted. The purpose of this analysis was to

---

[1]USAAVNC, *Rotary Wing Instrument Guide,* Fort Rucker, AL, Feb 1977.

[2]USAAVNC, DUFT, *Rotary Wing Basic Instrument Flight,* informal publication, Fort Rucker, AL, Oct 1976.

[3]FM 1-5, *Instrument Flying and Navigation for Army Aviators,* DA, 1976.

[4]AR 95-63, *Army Aviation Standardization and Instrument Program,* DA, 1976.

[5]DOD Flight Information Publication (Terminal), *Low Altitude Instrument Approach Procedures,* Vol. 6, South Central United States, The Defense Mapping Agency Aerospace Center, St. Louis Air Force Station, MO, 1977.

[6]USAAVNC Regulation 350-16, *The Uniform Flight Grading System,* (with changes), DA, 1970.

[7]*op. cit.,* Ref. 1.

[8]USAAVNC, *UH-1 Flight Simulator Handbook,* DA, 1977.

gain a working knowledge of the simulation system, its capabilities and the limitations relevant to implementation of the automated performance measurement system and grading. Results of this analysis are discussed in Chapter III.

Maneuver Analysis

A detailed analysis was then conducted of the automated Basic and Advanced Instrument maneuvers. This analysis required the determination of the general flight profile, the initial conditions and the exact performance requirements. Since much of this work involved consultations with SMEs, a list of common errors committed by student pilots was also compiled. The performance requirements and the common errors served as a basis for developing candidate measures.

Feasibility of Implementation

Once the scope of the performance measurement system and grading and diagnostics requirements had been established, it was necessary to establish that the physical implementation would be possible. The measurement and grading design and the information gained during the analysis of the UH1FS control system hardware and software, were used to develop a preliminary implementation design. Based on the implementation design and the known characteristics of the UH1FS control system, it was determined that implementation of the system and the required grading and diagnostic outputs could be achieved with only minor modifications of the proposed measures. This was fortunate, since any major conflict between the performance measurement system requirements and the implementation constraints would require extensive reworking of the performance measurement design.

Final Determination of Grading and Diagnostics System

Once it was determined that implementation was feasible, the final details of the grading and diagnostic system were completed. At this point, a related project, "Inflight Performance Assessment,"[9] was nearly complete. The form of the grading for the system was made compatible with that used for inflight grading. This compatibility provided uniformity and continuity between the inflight and automated grading procedures.

The specific diagnostic error messages were also developed at this time. The primary concern for the diagnostic error messages was that they be meaningful to, and understood by, student pilots, rated pilots, and IPs. An output format was designed for the maneuver grade and diagnostics that was consistent with their intended purpose and the physical constraints of the UH1FS.

Acceptance Test and Validity Test Plans

The final task was to develop acceptance test and validity test plans. Also, it became apparent during the course of the work that

---

[9] Childs, Jerry M. *Inflight Performance Assessment*, Interim Report, Manned Systems Sciences, Inc., Fort Rucker, AL, 14 November 1977.

supportive documentation would be necessary to explain the use of the system. The required contents of a handbook which describes the performance measurement system, its use, and interpretation of the output are described. A brief discussion of utility testing also was developed.

CHAPTER II

DEVELOPMENT OF MEASUREMENT SYSTEM DESIGN

MANEUVER ANALYSIS

MANEUVER SELECTION

Each of the ten automated Basic and Advanced Instrument maneuvers were reviewed to determine which maneuvers would be suitable for automated performance measurement. It was decided not to use all maneuvers in the interest of economy of time and effort, and also to insure that the implementation requirements would not exceed the practical capacities of the UH1FS computer system. The selection process was a balance between providing a sufficient number and type of maneuvers to allow meaningful performance measurement and restricting the choices to a minimum to prevent wasted effort in the event implementation did not prove practical.

The maneuvers were reviewed by reference to the available documentation,[10,11] transcripts of the automatic voice tape maneuver briefings and several runs through each maneuver in the UH1FS.

Performance measurement requirements were developed for six of the ten maneuvers. These six maneuvers are: (1) ADF Approach; (2) NDB Approach; (3) VOR Approach; (4) ILS Approach; (5) Backcourse ILS Approach; and (6) Holding at an Intersection. The flight profiles and performance requirements for these six maneuvers are described in the appendix.

Performance measurement requirements were not developed for four of the maneuvers. The Basic Instrument maneuvers, other than climbing and descending turns, were excluded because they are too simple for meaningful performance measurement. The Instrument Takeoff was excluded because of a reported lack of fidelity of the aircraft handling characteristics during takeoff. The Cross-Country maneuver was excluded because it emphasizes emergency procedures and not flight control. The Checkride maneuver was excluded because of its 1.5-hour length.

MANEUVER SEGMENTATION

The flight profile of each of the six selected maneuvers was diagramed and analyzed into maneuver segments. Segmentation was based on selecting distinctive points in the maneuver profile where the performance requirements changed significantly. Each segment can be categorized as a flight task with a distinct sub-goal. These characteristics of the segments can be

---

[10] *op. cit.*, Ref. 1

[11] *op. cit.*, Ref. 8

appreciated by reference to the maneuver descriptions described in the appendix. On three of the four approach maneuvers, for example, the initial segment is tracking to a fix, either a VOR or NDB beacon. The second segment is turning to parallel the outbound course and intercepting the outbound course. Clearly, these are distinctive and meaningful segments which can be easily understood by the pilot.

Specific performance requirements for each segment of each maneuver were developed by reference to the applicable publications[12,13,14,15,16] and consultation with IPs assigned to the Army Research Institute Field Unit and standardization pilots assigned to the Instrument Qualification Division of the Department of Undergraduate Flight Training at Fort Rucker, Alabama. Concurrently with the development of the performance requirements, a list of common errors committed by student pilots was also compiled.

MEASUREMENT AND START-STOP LOGIC DEVELOPMENT

MEASUREMENT DEVELOPMENT

The primary purpose of the measurement system is to produce data on which to base a grade for instrument flight performance. The secondary purpose is to provide diagnostic information about performance errors. The key requirement of the measurement system design is that it be relatively simple since the UH1FS computer system cannot accommodate an extensive amount of added software.

The first step in the measurement development process was to establish the specific critical variables for the six instrument flight maneuvers and to define allowable-error criteria for them. The critical variables were determined by analysis of the performance requirements for each segment of the six maneuvers. Desired values for each critical variable were established at the same time.

Allowable error tolerances were derived, to the extent possible, from the Army regulations and IERW training publications. Since performance criteria were not available for many of the critical variables selected, these were developed by discussion with SMEs. The error criteria, whether published or recommended by SMEs, defined a threshold separating satisfactory and unsatisfactory performance. It was decided, however,

---

[12] *op. cit.*, Ref. 1

[13] *op. cit.*, Ref. 2

[14] *op. cit.*, Ref. 3

[15] *op. cit.*, Ref. 4

[16] *op. cit.*, Ref. 5

that the measures would be more useful if the performance could be divided into more categories than satisfactory and unsatisfactory. A total of three error criteria for each variable was considered sufficient. This decision was partially influenced by the fact that a concurrent project for the development of inflight performance assessment measures uses three criteria levels for each of the assessment variables.[17] Aligning the number of criteria levels of the automated performance measurement system with those of the inflight performance assessment system would provide a desirable continuity between the two measurement techniques.

In using three criteria levels for each variable, it was decided that the second or middle criterion level would be considered the nominal dividing point for satisfactory and unsatisfactory performance. The first tolerance level would be more stringent than the second and would, therefore, nominally be the criterion for better than average or good instrument flight performance. The third criterion level would be more liberal than the second and would therefore be the nominal threshold for very poor performance.

Performance is measured in this application by a comparison of the difference between a sampled value and the desired value to the three tolerance levels. It did not seem reasonable, however, to compare each single value of the sampled variable to the tolerance criteria to determine if an error had been committed. Based on several considerations, which will be described presently, it was decided that for most variables a four-second running average would be computed and used as the fundamental datum to be compared to the criteria levels. Additionally, it was decided that the running average would have to exceed a tolerance level for a specified period of time before it would be registered as an error.

The reasons for adopting this form of error determination are as follows: First, transient or "spike" effects in the data due to either environmental factors, such as wind or turbulence, or noise in the instrument and control transducers and the computer itself will be suppressed by a running average.

Requiring that a variable exceed a tolerance level for a specific time was based on consideration of the perceptual and cognitive factors involved in instrument flight. A pilot cannot be aware of all instrument indications simultaneously. He adopts a scanning procedure where various instruments are sampled at various times. Therefore, it is unlikely that a pilot will notice an instantaneous or momentary departure of a variable from the desired value. Allowing for a certain time-out-of-tolerance before registering an error gives the pilot the opportunity to notice and correct the error. Second, if more than one variable is out

---

[17] *op. cit.*, Ref. 9

of tolerance, a pilot, particularly a student pilot, is apt to correct one variable at a time, although he may be fully cognizant of the additional out-of-tolerance conditions. Third, the pilot may have actually begun to correct a noticed error, but due to inertia in the aircraft and time lags in instruments, the variable may not come within tolerance for several seconds.

Taken together, it appeared that the use of a four-second running average for the critical variables and the use of a time-out-of-tolerance criteria was a realistic approach to performance measurement and compatible with the rate at which a human pilot can detect and correct errors.

As will be seen in Chapter III, the use of multiple criteria, computation of running averages and determining time-out-of-tolerance is relatively simple to implement.

START-STOP LOGIC DEVELOPMENT

A necessity of any automated flight performance measurement system is the ability to know when to begin and end the measurement. Not all measures are applicable throughout the entire course of a maneuver or the desired value for available change. For example, if an aircraft holding straight and level at 3000 feet makes a descent to 2000 feet and again holds straight and level, the initial desired value for altitude measurement would be 3000 feet; this measure must stop when the descent begins and the measure of altitude starts again when the aircraft has reached the new desired value of 2000 feet. This example, detecting the beginning and end of the descent, is the work of the start-stop logic.

The present automated performance measurement system is designed as a real-time system. The UH1FS control computer does not have the spare processing capacity nor peripheral memory for storing the massive amounts of data that are required to do postflight measurement analysis.

The technique developed in the present study for start-stop logic definition is a new and somewhat novel approach to the problem. Having an historical record is a good means of determining the intent behind a given change in an aircraft variable. It was realized, however, that it may not be necessary to maintain the historical data for the entire maneuver. Maintaining only 10 to 15 seconds of historical data on flight variables may be sufficient to determine whether a change in a variable was simply a corrective adjustment or the beginning or end of a major transition. It was decided, therefore, to maintain a 15-second history of all variables used for either measurement or start-stop logic definition. When a change in a start-stop logic variable is detected, the trend of the change is followed for a minimum of 10 seconds. If the trend is consistent over this period, there is little doubt that a major state transition is under way.

The beginning or end of the measurement segment is defined as the point where the start-stop variable change first occurred, i.e., 10 seconds in the past. Since the variables for measurement also have been maintained over the same period of time, it is a simple matter to pick up or cut off the data entering the measurement stream at the same point. Basing the start-stop logic on historical time data rather than instantaneous real-time data greatly increases the power of single start-stop logic conditions to detect major state transitions and screen out minor changes which are either performance errors or corrective adjustments.

This near-real-time approach to measurement combines advantages of both real-time and offline performance analysis. As will be seen in Chapter III, the implementation of near-real-time measurement and start-stop logic is extremely economical.

CONSOLIDATION OF MEASUREMENT AND START-STOP LOGIC VARIABLES

The performance measures and start-stop logic were developed independently for each maneuver. Once this was completed, a consolidated list of the measures and start-stop conditions was compiled. The objective of the consolidation was to minimize the number of unique measures and start-stop conditions required for the automated performance measurement system. By substitution and redefinition of some of the measures and start-stop conditions, it was possible to reduce the number of measured variables to 22 and the number of start-stop conditions to 16. Some of the same variables are used for both purposes.

Based on the performance criteria derived from published regulations and consultation with SMEs, desired values, specific error tolerance criteria values for three tolerance levels, and the corresponding time in seconds the variable must be out of tolerance before an error is registered, were assigned for each measure. The common sets of measures and start-stop logic conditions were used to restructure the performance measurement plan for each of the six automated Basic and Advanced Instrument maneuvers.

MEASURE DESCRIPTION

The following is a description of the specific measures used to assess instrument flight performance on the six automated Basic and Advanced Instrument maneuvers used in the UH1FS. The 22 measures, the desired values (when constant), the tolerance levels, the time-out-of-tolerance required before an error is registered, and an indication of whether the direction of error ($\pm$) will be part of the diagnostic error messages are shown in Table II-1.

The measure name indicates the variable or function that is being measured. The abbreviation in parentheses and the associated number are simply for convenience of reference. The desired value for most measures

TABLE II-1

SUMMARY OF MEASURES

#	MEASURE	DESIRED VALUE	TOLERANCE			TIME			SIGN
			Tol-1	Tol-2	Tol-3	Tm1	Tm2	Tm3	
1	Airspeed (AS)	90 Knots	± 5K	± 10K	±20K	5	5	5	y
2	Trim (TR)	0 Ball Width	± .25BW	± .5BW	± 1BW	5	5	5	n
3	Bank Angle (BA)	0^o	16^o	20^o	25^o	5	5	5	n
4	Average Turn Rate (ATR)	3^o/Sec	± $.15^o$/Sec	± $.3^o$/Sec	± $.6^o$/Sec	T	T	T	y
5	Altitude (ALT)	Variable	± 50 Ft	± 100 Ft	± 200 Ft	5	10	10	y
6	Minimum Altitude (MAT)	Variable	0 Ft	- 20FT	- 50 Ft	5	5	5	n
7	Rate of Descent (RD)	- 500 FPM	± 50 FPM	± 100 FPM	± 200 FPM	5	10	10	y
8	Rate of Climb (RC)	+ 500 FPM	± 50 FPM	± 100 FPM	± 200 FPM	5	10	10	y
9	Heading on Rollout (HOR)	Variable	± 5^o	± 10^o	± 20^o	I	I	I	n
10	Heading Tracking (HDT)	Variable	± 5^o	± 10^o	± 20^o	5	10	10	n
11	Time (TME)	Variable	± 5 Sec	± 10 Sec	± 15 Sec	T	T	T	y
12	NDB Tracking (NBT)	Variable	± 3^o	± 5^o	± 7^o	5	10	10	n
13	NDB Course Deviation (NCD)	0 Naut. Mi.	± .052 NM	± .087 NM	± .123 NM	5	10	10	n
14	NDB Course Position (NDP)	Variable	± 5^o	± 6^o	± 7^o	I	I	I	n
15	VOR Tracking (VRT)	Variable	± 2^o	± 3^o	± 5^o	5	10	10	n
16	VOR Course Deviation (VCD)	0 Naut. Mi.	± .035 NM	± .052 NM	± .087 NM	5	10	10	n
17	VOR Course Position (VCP)	Variable	± 2^o	± 3^o	± 5^o	I	I	I	n
18	Localizer Tracking (LZT)	0^o	± 1^o	± 2^o	± 3^o	5	10	10	n
19	Glideslope Tracking (GST)	0^o	± $.1^o$	± $.2^o$	± $.3^o$	5	10	10	y
20	VOR Tuning (VTN)	Variable		INCORRECT			I		n
21	OMNI Bearing Setting (OBS)	Variable	± 1^o	± 2^o	± 3^o	I	I	I	n
22	Radio Call Transmitted (RCT)	Mike Switch Closed	.	NO			I		n

is dependent upon the specific requirements for the maneuver segment. The three tolerance levels, used for all but two measures, indicate, respectively, the criteria thresholds for nominally good performance, minimum satisfactory performance and poor performance.

Tolerance level 2 is the important standard. If the pilot can maintain all variables within tolerance level 2, his performance is considered satisfactory. Tolerance level 1 and tolerance level 3 values were determined after tolerance level 2 values had been established in consultation with SMEs.

The three time values are the times, in seconds, that variables must exceed the respective tolerance levels to be registered as an error. For some measures, either a T or an I is shown. The T means total time and the I means instantaneous value. Under the "Sign" column, the y indicates that, yes, the direction of error will be shown in the diagnostic message. The n means, no, the error direction will not be shown in the diagnostic message. Choosing some measures to show the sign of the direction of the error rather than doing so for all was a design compromise in the interest of economy of implementation.

SPECIFIC MEASURES

1. Airspeed

For all maneuvers the pilot is required to maintain 90 knots at all times. The standard tolerance (tolerance level 2) allows deviations of plus or minus 10 knots, is well established both in the regulatory training publications and believed to be reasonable by the SMEs. A very good pilot probably will maintain his airspeed within 4 knots, and a very poor pilot may allow his airspeed to vary by 20 knots or more. In all cases, the airspeed must exceed the respective tolerance level for 5 seconds before an error is registered. The diagnostic error message will indicate whether the airspeed was above or below 90 knots.

2. Trim

The desired value for trim is 0 ball width deviation on the slip indicator. The tolerance values for trim have not been established. The SMEs considered it reasonable to expect a pilot to maintain the aircraft within 1/2 ball width trim at all times. A good pilot will keep the aircraft trimmed within a 1/4 ball width at all times, and a poor pilot may at times be one ball width or more out of trim. The time out of trim before an error is registered is 5 seconds in all cases. Indicating the direction out of trim was not considered to be a useful characteristic for the diagnostic error message.

3. Bank Angle

The 0° desired value for bank angle is appropriate only for a straight and level flight. In turns in the UH-1 aircraft, the desired angle of bank to maintain a standard rate turn is between 14 and 15 degrees. Initially, two bank angle measures were planned, one for straight and level and one for turning flight. In the interest of economy, it was reduced to a single measure. Since the pilot cannot keep the aircraft out of bank for any length of time without turning the aircraft, which would register as an error on some other measure, the bank angle measure was considered to be most necessary for turns.

During instrument flight, it should never be necessary for a pilot to exceed a 20 degree bank. It may be necessary for an average pilot to exceed 16 degrees of bank in an attempt to make good a 3-degree-per-second turn rate over an entire turning maneuver. A very good pilot will hold the proper bank angle for a standard rate turn throughout the turn, and should never exceed 16 degrees. A poor pilot may induce bank angles of 25 degrees or more. In all cases, the tolerance level must be exceeded for 5 seconds before an error is registered. It was not considered necessary to show the direction of the bank error in the diagnostic message since the error message would appear under a segment for a turn maneuver where the direction of the turn would be known.

4. Average Turn Rate

All turns during instrument maneuvers are required to be at a rate of 3 degrees per second. Tolerance values for deviation from this rate are not well established. The tolerance levels for good, average and poor performance were chosen to correspond to 5, 10 and 20 percent of the desired value, respectively. The average turn rate is computed by dividing total heading change by total turn time. Since the out of tolerance value is computed at the end of the turn, the time-out-of-tolerance values are not applicable. The sign of the deviation from the desired turn rate will be shown in the diagnostic error message.

5. Altitude

During the course of the maneuvers, the pilot must maintain the aircraft at various altitudes. Plus or minus 100 feet of altitude is a well established standard. A good pilot will probably maintain altitude within 50 feet of the desired value and a poor pilot may allow altitude to deviate 200 feet or more. According to the SMEs, it is axiomatic that the very good pilot will not only maintain variables very close to the desired value, but also quickly correct detected deviations. The poor pilot, on the other hand, is likely to allow variables to drift further out of tolerance and remain there for longer periods of time. Accordingly, only 5 seconds are allowed for altitude to exceed the first tolerance level before an error is registered. For the second and third tolerance levels, 10 seconds are allowed. The sign of the altitude error, whether high or low, will be shown in the diagnostic error message.

6. Minimum Altitude

The minimum altitude measure is used for most segments of the approach maneuvers, since the DOD FLIP Low Altitude Instrument Approach Procedures specify a minimum altitude which is never to be violated. The exact desired value of the minimum altitude is different for different segments of the maneuvers. Since the minimum altitude is never to be violated, there is no leeway for the first tolerance level. A pilot may, however, drift slightly below the minimum altitude, but should correct quickly. Therefore, a 20-foot error margin has been allowed for tolerance level 2 and a 50-foot error for tolerance level 3. The time-out-of-tolerance required before an error is registered is 5 seconds in all cases. The direction of error in the minimum altitude measure is implicit and need not be shown in the diagnostic error message.

7. Rate of Descent

IERW student pilots are taught to make all instrument descents at a rate of 500 feet per minute. The tolerance value for rate of descent error is not well established. It was the opinion of the SMEs that maintaining the rate of descent within 100 feet per minute would be satisfactory. The good pilot will maintain his rate of descent within 50 feet per minute of the desired value, and a poor pilot may allow his rate of descent to vary from the desired value by more than 200 feet per minute. The time out of tolerance allowed before an error is registered, 5 seconds for the first tolerance level and 10 seconds for the second and third, reflects the belief that the good pilot will correct a noticed error more quickly than the average or poor pilot. The direction of error will be shown in the diagnostic error message.

8. Rate of Climb

IERW student pilots are taught to make all instrument climbs at a rate of 500 feet per minute. As with the rate of descent, it was believed by the SMEs that a deviation of 100 feet per minute or less from the desired value would be satisfactory. A good pilot will maintain the desired rate of climb within 50 feet per minute, and a poor pilot may allow his rate of climb to deviate by 200 feet per minute or more. The time out of tolerance is the same as for rate of descent.

9. Heading on Rollout

This measure is used primarily at the termination of the inbound procedure turn of the approach maneuvers, where the pilot is required to roll out on the inbound heading. The exact heading depends on the particular maneuver. A heading deviation of plus or minus 10 degrees is a well established tolerance value for maintenance of heading. The SMEs believe that a good pilot will arrive at the correct heading on rollout within 5 degrees, and a poor pilot may be off by 20 degrees or more. The measure is made at the instant the aircraft becomes straight and level. Accordingly, the error is based on the instantaneous value of heading. The direction of the heading error will not be shown in the diagnostic error message.

10. Heading Tracking

During various segments of the maneuvers, the pilot is required to track a gyro compass heading. The exact heading is dependent upon the requirements of the particular segments of the maneuver. A 10-degree heading error is a well established standard tolerance. SMEs believe that a good pilot will maintain heading with 5 degrees, and a very poor pilot may allow his heading to drift by 20 degrees or more. The time-out-of-tolerance allowed before an error is registered reflects the belief that a good pilot will correct slight deviations quickly, while an average or poor pilot will maintain an error longer before correcting. The sign of the heading error will not be shown in the diagnostic error message.

11. Time

All of the maneuvers have time requirements in one or more segments. For example, all final approach segments of the nonprecision approach maneuvers have specified times from the final approach fix before a missed approach procedure must be executed. The time required depends on a particular segment of the maneuvers. A time tolerance is not well established. It was believed by the SMEs that the average pilot will time accurately within plus or minus 10 seconds. A good pilot should make his time good within 5 seconds, and a poor pilot may have a time error of 15 seconds or more. Since time is the basis for this measure, it is cumulative over the entire measurement segment and the T in the time-out-of-tolerance column reflects that total time is considered. The sign of the time error, whether too long or too short, will be shown in the diagnostic error message.

12. NDB Tracking

NDB tracking measures the ability of the pilot to maintain a course by reference to the ADF needle. The desired value for the NDB tracking depends on the segment of the NDB approach maneuver. SMEs consider 5 degrees or less tracking error to be satisfactory. A good pilot should maintain his track within 3 degrees, and a very poor pilot may allow his track to deviate by 7 degrees or more. The time out of tolerance allowed before an error is registered reflects the belief that a good pilot will correct a detected error more quickly than the average or poor pilot. The sign of the error will not be shown in the diagnostic error message. It is important to note that the NDB tracking measure is applicable only when the aircraft is one nautical mile or more from the NDB. Nearer than one nautical mile the convergence of the course radials is so rapid that an angular reference for a tolerance value cannot be used.

13. NDB Course Deviation

The NDB course deviation is the analog of the NDB tracking measure and is applied only when the aircraft is within one nautical mile of the NDB. Within this range, the aviator should be tracking the course heading indicated by the gyro compass rather than the ADF needle. The desired value is 0 nautical mile laterally with reference to the desired course. The tolerance values in nautical miles are the distance equivalents of 3, 5, and 7 degrees at one nautical mile from the NDB. The time out of tolerance allowed is the same as that for the NDB tracking measure. The sign of the measure is not shown in the diagnostic error message.

14. NDB Course Position

The NDB course position measure is used in the NDB approach problem when the aircraft rolls out on the inbound course. The tolerance values are larger than those for NDB tracking, since the loop antenna loses directional accuracy when the aircraft is banked. There is no well established criteria for angular error when rolling out on a course by reference to the ADF needle. The SMEs believe that rolling out within 6 degrees of the desired course or less is satisfactory. A good pilot should be able to roll out within 5 degrees of a desired course, and a poor pilot may be in error by 7 degrees or more. The measure is made at the instant the aircraft becomes straight and level, and, therefore, no time tolerance is allowed. The sign of the error will not be shown in the diagnostic error message.

15. VOR Tracking

VOR tracking is a measure of the pilot's ability to track a VOR course by reference to the course deviation indicator (CDI) needle. This measure is a direct analog of the NDB tracking measure. The tolerance levels are more stringent since the CDI is more sensitive than the ADF needle. The tolerance levels are 2, 3, and 5 degrees, respectively. The time out of tolerance allowable before an error is registered is 5 seconds for the first tolerance level and 10 seconds for the second and third. The direction of the error will not be shown in the diagnostic error message. The VOR tracking measure is used only when the aircraft is at a distance of one nautical mile or more from the VOR. Within one nautical mile, the radials converge so rapidly that it is not possible to navigate accurately by reference to the CDI. At one nautical mile or less, the aviator should maintain the correct course heading by reference to his gyro compass.

16. VOR Course Deviation

The VOR course deviation measure is a direct analog of the NDB course deviation measure. It is used only when the aircraft is within one nautical mile of the VOR. The three tolerance levels in nautical miles are equivalent to angular deviations of 2, 3, and 5 degrees respectively at one nautical mile from the VOR. The time-out-of-tolerance allowable before an error is registered is 5 seconds for the first tolerance level and 10 seconds for the second and third. The sign of the error will not be known in the diagnostic error message.

17. VOR Course Position

The VOR course position measure is a direct analog of the NDB course position measure. It is used in the VOR approach maneuver to determine the aircraft position relative to the desired inbound course when the aircraft rolls out of the inbound procedure turn. Because the VOR receiver is not sensitive to the bank of the aircraft, the tolerance values are the same as those used for the VOR tracking measure. Since the measure is made the instant the aircraft becomes straight and level, the time-out-of-tolerance allowed is not applicable. The sign of the error will not be shown in the diagnostic error message.

18. Localizer Tracking

Localizer tracking measures the ability of the pilot to remain on the localizer course for the ILS approach and localizer backcourse approach maneuvers. When coupled to the ILS, the CDI is twice as sensitive as it is for VOR tracking. Localizer tracking is always relative to the particular localizer course and, therefore, 0 degrees deviation is the desired value. The tolerance value for localizer tracking is not well established. SMEs believe that the average pilot should be able to maintain the aircraft within two degrees of the course line. A good pilot probably will maintain the aircraft within one degree, and a poor pilot may allow the aircraft to deviate by three degrees or more from the course line. The time-out-of-tolerance allowable before an error is registered is 5 seconds for the first tolerance level and 10 seconds for the second and third. The time-out-of-tolerance allowed before an error is registered reflects the belief that a good pilot will notice the error and make corrections more quickly than the average or poor pilot. The direction of the error will not be shown in the diagnostic error message. The localizer tracking measure is used only while the aircraft is one nautical mile or more from the localizer transmitter.

19. Glideslope Tracking

Glideslope tracking is a vertical analog of localizer tracking, and is used only in the final approach segment of the ILS approach maneuver. The desired value for the glideslope is always relative to the beam and is therefore 0 degrees. The glideslope indicator needle is 10 times as sensitive as the localizer CDI. A performance criteria for glideslope tracking is not well established. SMEs believe that maintaining a glideslope course within .2 degrees is satisfactory. A good pilot probably will maintain the glideslope course within .1 degree, and a poor pilot may allow the aircraft to drift off the glideslope by .3 degree or more. The time-out-of-tolerance allowable before an error is registered is 5 seconds for the first tolerance level and 10 seconds for the second and third. The time-out-of-tolerance allowed before an error is registered is a reflection of the fact that a good pilot is likely to notice and correct an error more quickly than the average or poor pilot. Because of the importance of glideslope error, particularly being below glideslope, the sign of the error for glideslope tracking will be shown in the diagnostic error message.

20. VOR Tuning

The pilot is required to retune his VOR radios during various segments of the maneuvers. Since radio communication is an important part of the instrument navigational procedures, this measure determines if the VOR has been tuned correctly at the proper time. Because of the nature of the measure, there is no tolerance value. The radio is either tuned correctly or it is not. Time-out-of-tolerance is not applicable to this measure. The radio frequency is sampled continuously during the appropriate period to determine if the pilot has correctly tuned the radio. The diagnostic error message does not indicate the direction of error of the tuning.

21. OMNI Bearing Setting

The OMNI bearing setting measure determines whether the pilot has adjusted the OMNI bearing selector (OBS) to the desired radial. It is basically a measure of precision. A criteria for accuracy of setting the OBS is not well established. SMEs believe that setting the OBS within two degrees of the desired radial is satisfactory. A good pilot will probably set the OBS within one degree of the desired radial and a poor pilot may be in error by 3 degrees or more. Time-out-of-tolerance is not applicable to this measure, and the OBS setting is sampled once at the appropriate time. The direction of the error is not shown in the diagnostic error message.

22. Radio Call Transmitted

This measure determines whether the pilot has made the required radio calls at the appropriate times. The measure is not dependent on the accuracy of the information transmitted but simply whether the aviator has closed the microphone switch for one second or more. Nc tolerance value is applicable. Either the radio call was made within the appropriate time frame or it was not. Time-out-of-tolerance also is not applicable to this measure. The microphone switch is sampled continuously within a specified time frame. Direction of error is not applicable to this measure and is not part of the diagnostic error message.

The above 22 measures can be considered to fall into three general categories: (1) aircraft control; (2) navigation; and (3) radio procedures. The first 8 measures--Airspeed, Trim, Bank Angle, Average Turn Rate, Altitude, Minimum Altitude, Rate of Descent and Rate of Climb--are generally directed at basic aircraft control. The categorization is not perfect since it can be argued that the Altitude and Minimum Altitude measures are related to navigation and that the Heading Tracking measure should be regarded as part of basic aircraft control. Heading on Rollout, Heading Tracking, Time, NDB Tracking, NDB Course Deviation, NDB Course Position, VOR Tracking, VOR Course Deviation, VOR Course Position, Localizer Tracking and Glideslope Tracking relate basically to navigation. VOR Tuning, OMNI Bearing Setting and Radio Call Transmitted are all measures of radio procedures. The grading system, to be described later does not distinguish among these sets of measures for purposes of producing a score. In terms of interpreting the diagnostics, however, they may provide a useful organizing concept for determining the relative strengths and weaknesses of the pilot's instrument flying ability.

IMPLEMENTATION CONSIDERATIONS

For the measures described above, it has been assumed that each variable being measured is sampled at a rate of one per second. Since these are all aircraft-related variables, they do not change at a rapid rate and one per second is considered an adequate sampling for measurement purposes. A four-second running average value has been specified for all the measurement variables. Upon implementation, it may turn out that this running average time changes too slowly to be useful. If this is the case, it should be a simple matter to change the running average time or the computational nature of the running average value.

Many of the tolerance and time-out-of-tolerance values are not well established, but are based on the considered opinions of the SMEs. It may turn out, once the system is implemented, that they are either too stringent or too liberal. Empirical testing of the measures will quickly determine their suitability. Since they will be organized as a single table, it will be a relatively simple matter to change them to more suitable values.

START-STOP LOGIC CONDITIONS

Sixteen start-stop logic conditions are used to begin and end measurement in the six automated Basic and Advanced Instrument maneuvers implemented in the UH1FS. The start-stop conditions are used in a sequential manner. That is, a single condition starts or stops a measurement segment. Measurement segments should be distinguished from maneuver segments. A maneuver segment is a portion of an instrument maneuver with a particular task goal and begins and ends with a major transition in one or more aircraft variable. A measurement segment is a sub-portion of a maneuver segment during which time one or more variables are measured. The following is a short discussion of each measurement start-stop logic condition.

1. START

This is the beginning of each maneuver. The pilot or IP presses the UNFREEZE or CONTINUE button in the UH1FS cockpit.

2. CPS

Many of the measurement segments begin on the same condition that ended the previous segment. CPS stands for Close of Previous Segment and is used extensively in the measurement sequences outlined in the appendix.

3. RTR

Aircraft turns to the right. This condition is triggered when the running four-second average of turn rate is greater than or equal to 2°/second to the right.

4. LTR

Aircraft turns to the left. This condition, like the right turn, is triggered when the running four-second average turn rate to the left is greater than or equal to 2°/second.

5. SL

Aircraft is straight and level. This condition always terminates a measurement segment begun by *either a right or a left turn. It is* triggered when the four-second running average turn rate is less than .5°/second.

6. ACF-1

Aircraft is one nautical mile from a stated or understood fix, either a radio beacon or an intersection. It is triggered at any time the aircraft crosses, in either direction, the circle around the fix one nautical mile in diameter.

7. CCL-x°

Aircraft crosses the x° course line at a fix. The reciprocal course line extension is understood. This condition is used to detect when the aircraft passes over or is adjacent to a given fix.

8. ACD-x

Aircraft is x nautical miles lateral distance or less from a stated or understood course line, usually defined by a radial from radio fix. The aircraft always will be moving toward the course line.

9. TIM-x

Time period x, in seconds, has elapsed. This condition is usually used to provide a buffer of time between the end of one measurement segment and the beginning of another.

10. HDA-x°

Aircraft heading is within plus or minus 5 degrees of x°. The condition is triggered when the running four-second average of aircraft heading is within 5 degrees of heading x°.

11. ALTB-x

Aircraft altitude is equal to or below x feet. This condition is always used when the aircraft is descending. Its usual purpose is to stop measurement of rate of descent, usually 100 feet above the target altitude.

12. ALTA-x

Aircraft altitude is equal to or above x feet. This condition is triggered when during an ascent, the aircraft altitude equals or exceeds the designated x altitude. It is usually used to stop a measurement segment in which rate of climb is being measured. X is normally 100 feet below the target altitude.

13. DES

Aircraft is descending. This condition triggers when the four-second running average of vertical airspeed is equal to or greater than 200 feet per minute downward.

14. CMB

Aircraft is climbing. This condition is triggered when the four-second running average vertical airspeed is equal to or greater than 200 feet per minute upward.

15. TPC

Torque pressure is equal to or greater than 27 psi. Normal cruise power is approximately 24 psi. This condition is triggered when the four-second running average of torque pressure is equal to or greater than 27 psi. This condition is principally used to terminate measurement during the final approach segment and to begin measurement during the missed approach segment.

16. RRF

Aircraft receives radar fix. This condition occurs only once during the Localizer Backcourse approach. The pilot is informed by radio that radar has placed him at the point to begin his final approach descent.

The sixteen measurement start-stop logic conditions are summarized in Table II-2.

FATAL ERRORS

The sequence of start-stop logic conditions is essentially a means of tracking the aircraft throughout all portions of the maneuver. Because of the lack of sophistication of the performance measurement system, it is not possible to recover measurement capability if the start-stop conditions are not triggered and, consequently, the track of the aircraft progress through the maneuver is lost. Also, a pilot may perform so poorly that he loses control of the aircraft or is unable to navigate the required profile of the maneuver. In either of these two cases, performance measurement becomes meaningless and will be terminated. Termination of measurement is based on violation of certain conditions. These conditions are referred to as fatal errors.

There are 8 possible types of fatal errors based on: (1) excessively high or low airspeed; (2) excessive bank angle; (3) excessive rate of descent; (4) excessive altitude errors; (5) excessive time within a maneuver segment; (6) violation of airspace limits; (7) turning in the wrong direction; and (8) improperly set radio frequencies for beginning of the maneuver. The first three of these fatal errors have standard criteria for all maneuvers. That is, if airspeed is less than or equal to 60 knots or greater than 120 knots during any maneuver, measurement is terminated. Similarly, a bank angle equal to or in excess of 30 degrees or a rate of descent equal to or greater than 1000 feet per minute at any time during any maneuver is considered a fatal error. The remaining fatal error categories are specific to the particular maneuvers and the maneuver segments.

In the event that a fatal error occurs, scoring of the maneuver will not be possible. Diagnostics, however, will be printed out. This is discussed further in the next section. The specific fatal errors for each maneuver are shown in the appendix.

GRADING SYSTEM

PURPOSE

The purpose of the grading system is to produce a single composite score reflecting the pilot's overall performance on each of the Basic and Advanced Instrument maneuvers. The maneuver score will be of most use to training managers for evaluating individual and group progress through the instrument training phase. It will also allow the individual student pilot to know his performance capability relative to that of other students or his own past performance.

The key characteristic of the grading system is that the score is based on absolute criteria. No account is taken of the pilot's past experience or amount of training received.

TABLE II-2

SUMMARY OF MEASUREMENT START-STOP LOGIC CONDITIONS

CODE	EXPLANATION
START	Unfreeze or Continue (beginning of maneuver)
CPS	Close of previous measurement segment
RTR	Right Turn - Running 4-second average of turn rate greater than 2^{o}/sec to right
LTR	Left Turn - Running 4-second average turn rate greater than 2^{o}/sec to left
SL	Straight and Level flight; Running 4-second average turn rate less than $.5^{o}$/sec
ACF-1	A/C 1 nm from stated or understood fix (beacon or intersection)
CCL-x^{o}	Cross course line x at fix (reciprocal extension of course line understood)
ACD-x	Aircraft distance (x nm) orthogonal to stated or understood course line
TIM-x	Time period, X seconds
HDA-x^{o}	Heading 5 second average x^{o} $\pm 5^{o}$
ALTB-x	Altitude below x feet
ALTA-x	Altitude above x feet
DES	Descent VAS more than 200 fpm downward
CMB	Climb - VAS greater than 200 fpm upward
TPC	Torque pressure for climb greater than 27 psi
RRF	Receive radio fix (occurs only during Localizer Backcourse Approach)

CURRENT GRADING SYSTEM

The current grading system, as of November 1977, for instrument maneuvers is the same in the UH1FS as in the actual aircraft. After completion of an instructional period, the IP assigns a letter grade--A, B, C, or U (unsatisfactory)--for performance of a particular maneuver or series of procedures. The grade is largely based on the IP's judgment, although there are some explicit performance criteria. In arriving at a grade, the IP takes into account the amount of training received by the student. In practice, it has been found that most students predominately receive B grades which provide no information for training management other than the student's performance has been judged by the IP to be satisfactory. Although a C is defined as satisfactory, in practice it is considered a poor grade which, along with any U grade, must be explained by the IP in writing on the daily grade slip. Grades of A are rarely given.

RECOMMENDED GRADING SYSTEM

In contrast to the above situation, the grading system recommended for use in the UH1FS, which is compatible with the recommended inflight grading system[18] is based on performance relative to a specific standard for each aircraft control component of the maneuver, i.e., airspeed, heading, etc., as discussed previously. The grade is therefore criterion referenced and objective because the process by which the performance measures lead to a composite grade is explicit and unambiguous. Since the standards of performance do not change as a function of training time, progress toward the final desired proficiency level can be seen by improvement in the grade.

The recommended format for the grading system is a six-point numerical scale ranging from one (1) to six (6). A score of 1 indicates the worst performance level, and 6 indicates the best performance level. Grades within the range of 1 to 3 are considered to reflect degrees of unsatisfactory performance, and grades within the range of 4 to 6 are considered to reflect degrees of satisfactory performance.

The overall maneuver grade is based on scores determined for each maneuver segment. Segment scores are derived by determining whether the measures applied within each segment has exceeded one of the three tolerance levels described in the previous section. Recall that tolerance level 2 is considered the dividing line between satisfactory and unsatisfactory performance. If any measure is in the unsatisfactory range, i.e., exceeds tolerance level 2, the segment score will be in the unsatisfactory range. In turn, if any segment score is in the unsatisfactory range, the maneuver grade also will be in the unsatisfactory range. How the

---

18 *op. cit.*, Ref. 9

exact segment scores and maneuver grade will be determined within the satisfactory and unsatisfactory ranges will be described in turn.

SEGMENT SCORES

The segment score within either the satisfactory or unsatisfactory range is determined by the number of measures that exceed particular tolerance levels. Within the satisfactory range, i.e., no measures exceeding tolerance level 2, the number of measures exceeding tolerance level 1, the most stringent tolerance level, determines the grade. Within the unsatisfactory range, the number of measures exceeding tolerance level 2 or tolerance level 3 determines the segment grade.

Within the satisfactory range a segment score of 6 is assigned if all the measures are within tolerance level 1. A score of 5 is assigned if only some measures are within tolerance level 1. A score of 4 is assigned if all the measures exceed tolerance level 1.

Determination of the segment score within the unsatisfactory range is also simple. The highest grade achievable is a 3, which is assigned if no measure exceeds tolerance level 3 but some measures exceed tolerance level 2. A score of 2 is assigned if no measures exceed tolerance level 3 but all measures exceed tolerance level 2. If one or more measures exceed tolerance level 3, a score of 1 is assigned. Table II-3A summarizes the criteria for each segment score.

For ease of understanding, the criteria for a score is expressed as a score falling within a performance band. A performance band is simply the range of performance that falls on one side or the other of a tolerance level. Since there are three tolerance levels, four bands are defined for which performance is: (1) better than tolerance level one; (2) between tolerance levels 1 and 2; (3) between tolerance levels 2 and 3; and (4) worse than tolerance level 3.

MANEUVER GRADES

Maneuver grades are derived from segment scores in a manner analogous to the determination of the segment scores. A maneuver grade in the satisfactory range (4 - 6) can occur only if all segment scores are 4 or above. A grade of 6 is assigned if no segment score is less than 5 and at least one segment score is 6. A grade of 5 is assigned if no segment score is less than 4 and at least one segment score is 5 or 6. A grade of 4 is assigned if all segment scores are 4.

A maneuver grade in the unsatisfactory range (1 - 3) can occur only if all segment scores are 3 or less. A grade of 3 is assigned if no segment score is less than 3. A grade of 2 is assigned if one or more segment scores is a 2 but none less than 2. A score of 1 is assigned if any segment score is a 1. Table II-3B summarizes the criteria for each maneuver grade.

Table II-3

CRITERIA FOR ASSIGNMENT OF SEGMENT SCORES AND MANEUVER GRADES BY THE UH1FS AUTOMATED GRADING SYSTEM

A. SEGMENT SCORING

SCORE	CRITERION
6	All measures within performance band 1
5	Some measures within performance band 2
4	All measures within performance band 2
	Satisfactory

	Unsatisfactory
3	Some measures within performance band 3
2	All measures within performance band 3
1	One or more measures in performance band 4

B. MANEUVER GRADING

GRADE	CRITERION
6	No segment score less than 5; one or more segment scores of 6
5	No segment score less than 4; one or more segment scores of 5 or 6
4	No segment score less than 4
	Satisfactory

	Unsatisfactory
3	No segment score less than 3
2	No segment score less than 2
1	One or more segment scores of 1

Producing maneuver grades by a two-step process, i.e., determining segment scores, then determining the maneuver grade, is recommended for several reasons. First, performance errors are likely to be grouped by segments rather than by type of measure. That is, a segment may be difficult and have a low score due to errors on several different measures rather than consistent errors for specific measures such as altitude, airspeed, etc., occurring in several segments. Segment scores also provide more information to the pilot or IP by giving an intermediate reference for performance between the global maneuver grade and the detailed, single diagnostic message. Finally, producing a segment score presents no particular implementation problem. If, after experience with the measurement system, the segment score is found not to be useful, it can be easily deleted and maneuver grades can be computed directly from the performance measures.

The choice of six grade levels, based on the *recommended inflight* grading system, was not arbitrary. Since the recommended inflight grading system requires recording of selected variables, i.e., heading, altitude, etc., by the IP, the amount of data that can be obtained is necessarily limited. It was determined that distinguishing six levels of performance was the maximum resolution that could be obtained with the limited inflight data. The current inflight assessment system allows for only four levels of performance. Future developments in both the inflight and automated UH1FS performance measurement systems may allow the number of levels to be increased. For the moment, it appeared to be an important consideration that there be continuity in the two grading systems. For research purposes, it would be a simple matter to have the automated performance measurement system produce more than six grade levels. This type of refinement, however, must await implementation.

It should be noted that an error for a particular measure, i.e., airspeed, etc., is counted only once during a maneuver segment. As will be seen in Chapter III, a distinction is made between *maneuver* segments and *measurement* segments. Several measurement segments make up a maneuver segment. A particular measure frequently occurs during several measurement segments. For scoring purposes, however, only the most severe error that occurred for a particular measure during a *maneuver* segment is used for scoring and diagnostic message purposes.

DIAGNOSTICS

In addition to providing segment scores and a composite maneuver grade, the automated performance system will produce diagnostic error messages to tell the student pilot and his IP which elements of performance were within what performance bands during each segment of the instrument maneuver flown.

The diagnostic error messages reflect the basic philosophy of the automated performance measurement system. Critical variables of aircraft control, navigation and radio procedures are measured and errors, departure of critical variables beyond the specified tolerance level, are reported. The diagnostics do not relate to pilot performance per se. That is, they do not tell the pilot what control errors he made that produced the critical variable error. Interpretation of the critical variable error in terms of what deficiency of the pilot caused the error is left to the IP. It is likely that the interpretation of the diagnostics by the IP will take into account the pattern of errors within the segments and throughout the entire maneuver.

The diagnostic error messages may also be of interest to training managers. That is, patterns of errors that occur frequently for a large number of student pilots or persist throughout most of the instrument training phase may indicate specific target areas for training improvement or intensification. On the other hand, the absence of certain types of errors may suggest that certain training elements can be shortened or eliminated.

A single diagnostic message is associated with each of the 22 measures described in an earlier section of this chapter. There are, therefore, no interpretive elements between the occurrence of the error and its reporting as a diagnostic message.

All 22 diagnostic error messages are shown in Table II-4. Each message is a clear text sentence with one or two variable fields which indicate the value of the tolerance level exceeded and, when appropriate, the direction of the error in terms of the desired value, i.e., "greater than" or "less than." To minimize the number of characters that must be printed for each diagnostic, the symbol ">" is used for "greater than" and the symbol "<" is used for "less than."

The first few words of each diagnostic error message names the measure which produced the error message. This allows the pilot or IP quickly to scan the lefthand portion of the error message output to determine the nature of the errors committed during the maneuver. On the left most portion of the page, a symbol indicating the performance band, i.e., (blank), -, or * is printed so that the pilot or IP can scan the righthand margin of the output and determine where the most serious errors occurred. Each diagnostic message requires only one line of print. The complete form of the printed output is described in the next section.

PRINTED OUTPUT FORMAT

The printed output for each maneuver will consist of three sections: (1) a header section with spaces for entering the pilot rank and name, and the date. Since the UH1FS has no keyboard to enter alphanumeric information, this information will be written on the output form either by the pilot, his IP, or the console operator. The name of the maneuver and the cockpit number will be printed by the automated performance measurement system. (2) The overall numerical grade for the maneuver and some modifying information, and (3) the name of each segment, the segment score and the diagnostic error messages for each segment of the maneuver.

Header Information

The recommended information elements of the header area are:

1. Name of Pilot________Rank ( )_______________________________
   First Name MI Last Name
2. Date____________ dd (day)/mm (month)/ yy (year) or julian date
3. Maneuver Name____
   (2. and 3. will be printed by the automated performance measurement system.)

The maneuver names to be printed are:

a. BASIC INST - CMB AND DSD TURNS

b. NDB RWY 5 COLUMBUS METROPOLITAN

c. VOR A DOTHAN

d. ILS RWY 9 DANNELLY FIELD

e. LOC BC RWY 13 DOTHAN

f. HOLDING SEALI INTERSECTION

Grade

The composite grade for the maneuver will be a number (N) from 1 to 6. The basis for this grade was discussed previously. The format for the grade is:

MANEUVER GRADE: N

Segment Scores and Diagnostic Error Messages

For each maneuver the segment score appears on the line with the segment title. The segment titles for the six maneuvers are shown in Table II-5. The diagnostic error messages follow on succeeding lines.

The 22 diagnostic error messages are shown in Table II-4. Each message has a total length of less than 80 characters so that each message will require only one line of print. The performance band for each measure is shown by the symbols in the righthand column. For performance band 1, no message is printed. For performance band 2, the message is printed with no symbol in the righthand print column. For

Table II-4

DIAGNOSTIC MESSAGES FOR UH1FS PERFORMANCE MEASURES
(Only one of the particular symbols and values shown in parentheses are printed.)

MEASURE NO.	MESSAGE	
1	Airspeed (> <) 90 knots by (5, 10, 20) Knots	(,-,*)
2	Trim Error > (.25, .50, 1.0) Ball Width	(,-,*)
3	Bank Angle > (16, 20, 25) Degrees	(,-,*)
4	Average Turn Rate (> <) (.15, .3, .6) Deg/Sec of 3 Deg/Sec	(,-,*)
5	Altitude (> <) Required Altitude by (50, 100, 200) Feet	(,-,*)
6	Minimum Altitude Violated by > (20, 50) Feet for 5 Seconds	(,-,*)
7	Rate of Descent (> <) 500 Feet Per Minute by (50, 100, 200) Feet Per Minute	(,-,*)
8	Rate of Climb (> <) 500 Feet Per Minute by (50, 100, 200) Feet Per Minute	(,-,*)
9	Heading on Rollout Error More Than (5, 10, 20) Degrees	(,-,*)
10	Heading Tracking Error More Than (5, 10, 20) Degrees	(,-,*)
11	Total Time Error (> <) Required Time by (5, 10, 15) Seconds	(,-,*)
12	NDB Course Tracking Error > (3, 5, 7) Degrees Beyond 1 Mile From Station	(,-,*)
13	NDB Course Tracking Error > (3, 5, 7) Degrees Within 1 Mile From Station	(,-,*)
14	NDB Course Position Error > (5, 6, 7) Degrees on Rollout	(,-,*)
15	VOR Course Tracking Error > (2, 3, 5) Degrees Beyond 1 Mile From Station	(,-,*)
16	VOR Course Tracking Error > (2, 3, 5) Degrees Within 1 Mile From Station	(,-,*)
17	VOR Course Position Error > (2, 3, 5) Degrees on Rollout	
18	Localizer Tracking Error > (1, 2, 3) Degrees	
19	Glideslope Tracking Error (> <) (.1, .2, .3) Degrees (> means above and < means below Glideslope)	(,-,*)
20	VOR Radio Tuned to Wrong Frequency	-
21	OBS Setting Error > (1, 2, 3) Degrees	(,-,*)
22	Radio Call Not Transmitted at Required Time	-

performance band 3, the symbol "-" appears in the righthand print column. For performance band 4, the symbol "*" appears in the righthand print column. An example of the recommended printout is shown in Figure II-1.

The automated measurement system will operate in two modes: the automatic mode (AUTO) or the checkride mode (CK-RIDE) mode. For output format description it is only necessary to state that in the AUTO mode only the header information score, or fatal error indicator, will be printed. The diagnostic error messages will not be printed. In the CK-RIDE mode, the score, or a fatal error indication, will be printed, plus full diagnostics. In the event a fatal error occurs, no score is printed. The words "FATAL ERROR" and the source of the fatal error are printed. The FATAL ERROR source messages are: (a) AIRSPEED, (b) BANK ANGLE, (c) DESCENT RATE, (d) ALTITUDE, (e) RADIO FREQ, (f) AIRSPACE, (g) TIME, and (h) TURN DIRECTION.

Figure II-1

EXAMPLE OF PRINTED OUTPUT FOR UH1FS PERFORMANCE MEASUREMENT
(Diagnostic error messages for three segments only are shown.)

	George E. Flyer	123-45-6789	29 Feb 78	CKPT #2
RANK	NAME	SSN		

MANEUVER: VOR A DOTHAN

MANEUVER GRADE: 1

ERRORS:

SEGMENT: INITIAL TRACKING TO VOR	SCORE: 3
AIRSPEED > 5 KNOTS OF 90 KNOTS	
TRIM ERROR > .50 BALL WIDTH	-
SEGMENT: TURN AND INTERCEPT OUTBOUND COURSE	SCORE: 3
AVERAGE TURN RATE < .2 DEG/SEC OF 3 DEG/SEC	
MINIMUM ALTITUDE VIOLATED BY 20 FEET FOR 5 SECONDS	-
OBS SETTING ERROR > 1 DEGREE	
SEGMENT: TRACKING OUTBOUND	SCORE: 1
TRIM ERROR > .50 BALL WIDTH	-
VOR COURSE TRACKING ERROR > 7 DEGREES	*

Table II-5

MANEUVER AND MANEUVER SEGMENT TITLES
FOR DIAGNOSTIC ERROR MESSAGE SECTION OF OUTPUT

CLIMBING AND DESCENDING TURNS

1	Straight and Level
2	Climbing Left Turn
3	Straight and Level
4	Descending Right Turn
5	Straight and Level
6	Climbing Left Turn
7	Straight and Level
8	Descending Right Turn
9	Straight and Level
10	Level Left Turn

NDB APPROACH

1	Initial Tracking to Beacon
2	Turn and Intercept Outbound Course
3	Tracking Outbound
4	Procedure Turn Outbound
5	Procedure Turn Inbound
6	Tracking Inbound
7	Beacon Inbound
8	Missed Approach

VOR APPROACH

1	Initial Tracking to VOR
2	Turn and Intercept Outbound Course
3	Tracking Outbound
4	Procedure Turn Outbound
5	Procedure Turn Inbound
6	Tracking Inbound
7	VOR Inbound
8	Missed Approach

-continued-

Table II-5

ILS APPROACH

1 Initial Tracking to Beacon
2 Turn and Intercept Outbound Course
3 Tracking Outbound
4 Procedure Turn Outbound
5 Procedure Turn Inbound
6 Tracking Inbound
7 Glideslope Inbound
8 Missed Approach

LOCALIZER BACKCOURSE APPROACH

1 Intercept Localizer Course
2 Tracking Inbound to Fix
3 Fix Inbound
4 Missed Approach

HOLDING AT INTERSECTION

1 Initial Tracking to Fix
2 Entry Right Turn Outbound
3 Entry Track Outbound
4 Entry Right Turn Inbound
5 Entry Track Inbound
6 10 14 Right Turn Outbound - (1, 2 or 3)
7 11 15 Track Outbound - (1, 2 or 3)
8 12 16 Right Turn Inbound - (1, 2 or 3)
9 13 17 Track Inbound - (1, 2 or 3)

repeated 3 times

CHAPTER III

UH1FS SYSTEM ANALYSIS AND DESIGN IMPLEMENTATION REQUIREMENTS FOR AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM

This chapter is divided into two parts. The first part is an analytic description of the computer equipment and software which supports instrument flight training in the UH1FS. The second part is a description of the software implementation design for the automated performance measurement and grading system.

UH1FS SYSTEM DESCRIPTION

The UH1FS system is a composite of equipment and software which provides four independent instrument training environments (cockpits) that are similar to the UH-1 helicopter. Each cockpit is mounted on a 5-degree-of-freedom motion base. The discussion below is limited to the computer hardware and software directly involved in running instrument flight simulation. That is, only the real-time processes of simulation will be considered. There will be no discussion of non-real-time processes such as preparation of maneuver profiles or running of diagnostic programs for hardware and software checking.

COMPUTER SYSTEM HARDWARE

The real-time hardware system is shown in Figure III-1. It consists of three computers; two Model 516 Honeywell and one Model 620/L100 Varian computers. The Honeywell computers do most of the simulation work. The Varian is used only to show information on the CRT displays located in each of the cockpits and at the simulator control console. The computers are interconnected to allow the rapid transfer of large amounts of data between computer memories. Special hardware, called an Inter-Computer Communication Unit (ICCU), is used for this purpose. Each of the Honeywell computers has a disk memory which is used to store both programs and simulation data. The major connection, or interface, between the four cockpits and the control console is through the No. 1 Honeywell computer. This same computer also has a real-time clock which drives the entire simulation system.

UH1FS SOFTWARE DESCRIPTION

Basic functions (real-time software tasks) performed by each computer in the system are listed in Table III-1. As shown in the table, the principal computer used to implement the mathematical model of the simulation, is the No. 1 Honeywell computer. Part of the simulation mathematical model is performed in the No. 2 Honeywell computer.

Timing is critical for the operation of the simulation system. All events such as mathematical computations, transfer of data between computers, between the computers and the disk, and between the cockpits

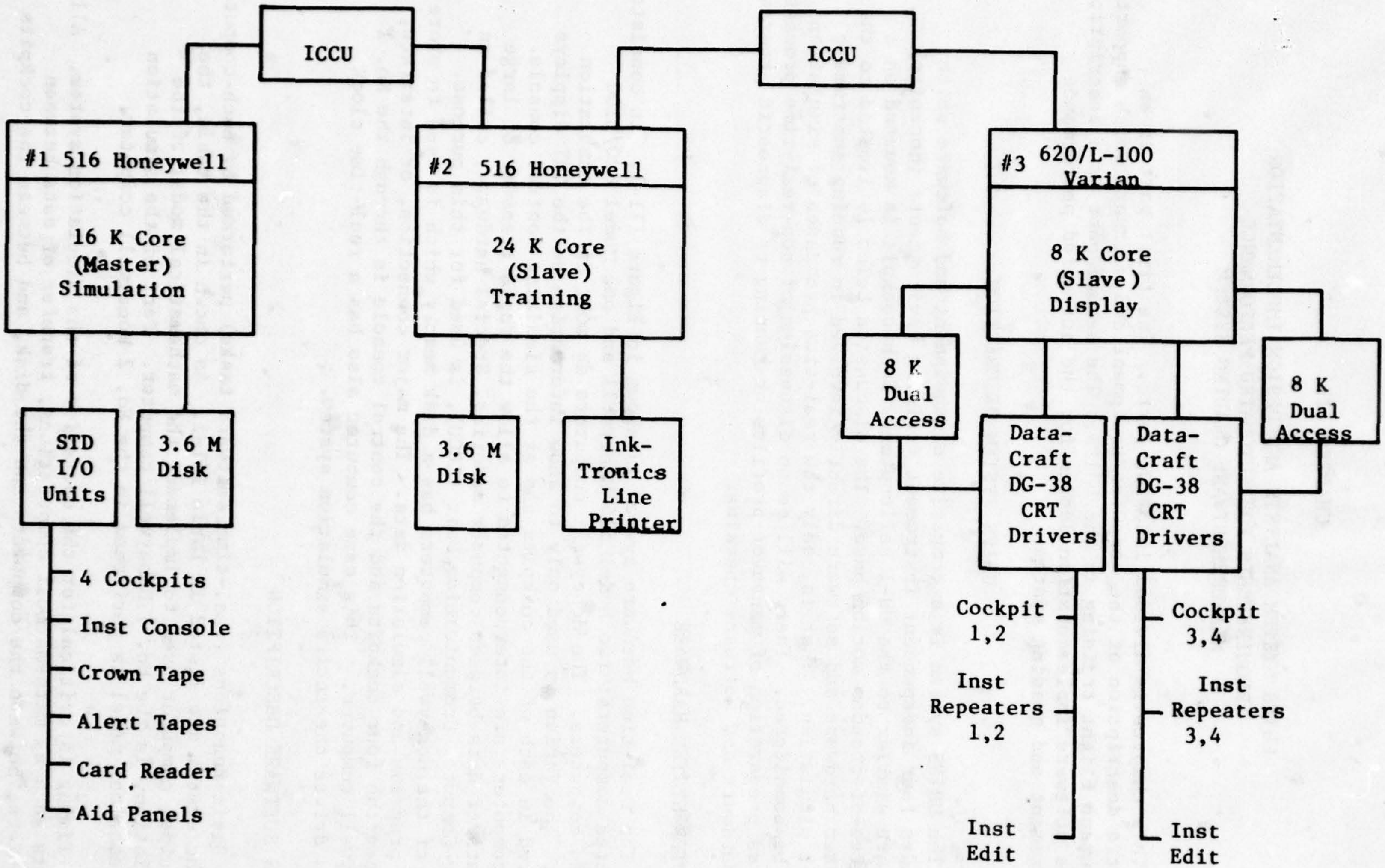


Figure III-1
UH1FS COMPUTER GROUP

TABLE III-1. DISTRIBUTION OF FUNCTIONS (REAL-TIME SOFTWARE TASKS) AMONG THE UH1FS SYSTEM COMPUTERS

#1 Honeywell Computer	#2 Honeywell Computer	Varian Computer
Simulation Software Tasks	**Simulation Software Tasks**	**Hardware Controlled**
prob freeze	main rotor	cockpit CRT's
record/playback	auto pilot	control console CRT's
EOM	malfunction control	
aircraft instruments		
inst instruments	**Training Software Tasks**	
sounds	auto-train select	
VHF navigation	co-pilot (demonstration)	
flight controls	wind adaptive	
motion base	performance indicator	
power plant	procedure indicator	
inst comm/pay	alert processing	
UHF/FM comm	card reader control	
electrical		
LF/ADF pay	**Other Software Tasks**	
fuel system	on-line editor	
GCA	plot control	
IFF	off-line editor	
Hardware Controlled	**Hardware Controlled**	
1-2 data transfer	2-1 data transfer	
disk interface	2-620 data transfer	
analog I/O	disk interface	
Digital I/O	printer interface	
audio tapes		

and the computers are allocated a certain amount of time within which the event must be completed. The entire sequence of events repeats cyclically. If the allocated amount of time for an event expires before an event is complete (processing capabilities of the system have been temporarily exceeded), either the results of the event are ignored as if they have never happened during a particular cycle or the failure to complete the event causes an error which may or may not terminate the entire simulation. Since four cockpits are being controlled independently, all the events in the simulation processes must be repeated four times, once for each cockpit. The primary reason for having three computers in the simulation system instead of one is that it is impossible to do all the processing required on one Honeywell computer within each cycle. The processing requirements, or tasks, have therefore been divided among three computers.

The basic flow of software processing activities in the two Honeywell computers is illustrated in Figure III-2. Note that there are two basic chains of processing in the No. 1 Honeywell computer and one in the No. 2 Honeywell computer. Note also the data transfers which occur between the two computers. The first chain, A, is the cockpit data transfer in and out (I/O) sequence. The second chain is the simulation mathematical model. The third chain, C, in the No. 2 Honeywell computer is also part of the simulation mathematical model. Each element of the cockpit I/O is addressed 16 times per second. Early in the processing sequence data are transferred to the No. 2 Honeywell computer through the ICCU, followed by an end of record (EOR) code which allows the computer to proceed with its processing tasks, Chain C, parallel in time with Chains A and B. Later, data are transferred back to the No. 1 Honeywell computer. The software tasks associated with the training functions, AUTO-TRAIN, are then processed in the No. 2 Honeywell computer. The detailed training software analysis, therefore, is focused on the programs in this computer.

Automatic Training System

The AUTO-TRAIN software provides the means of controlling the training use of the UH1FS. As mentioned in Chapter I, AUTO-TRAIN has three modes of operation; SEMI-AUTO, AUTO and CK-RIDE. The SEMI-AUTO mode is the least complex in the AUTO-TRAIN system. It allows any cockpit to be placed at specific points in the gaming area and also allows insertion of malfunctions into the various helicopter systems. Once a cockpit has been established at an initialization point, the pilot is free to "fly" the helicopter anywhere within the gaming area. The AUTO-TRAIN system in this mode is relegated to a historical tracking role and preserves for playback the most recent five minutes of the flight profile flown.

The AUTO mode is an expansion of the SEMI-AUTO mode. In this mode, however, the AUTO-TRAIN system uses a description of the desired flight profile to be flown. Using this information, the desired flight profile can be flown as a demonstration. When the pilot flies the desired profile eleven of the flight variables are monitored by AUTO-TRAIN. If

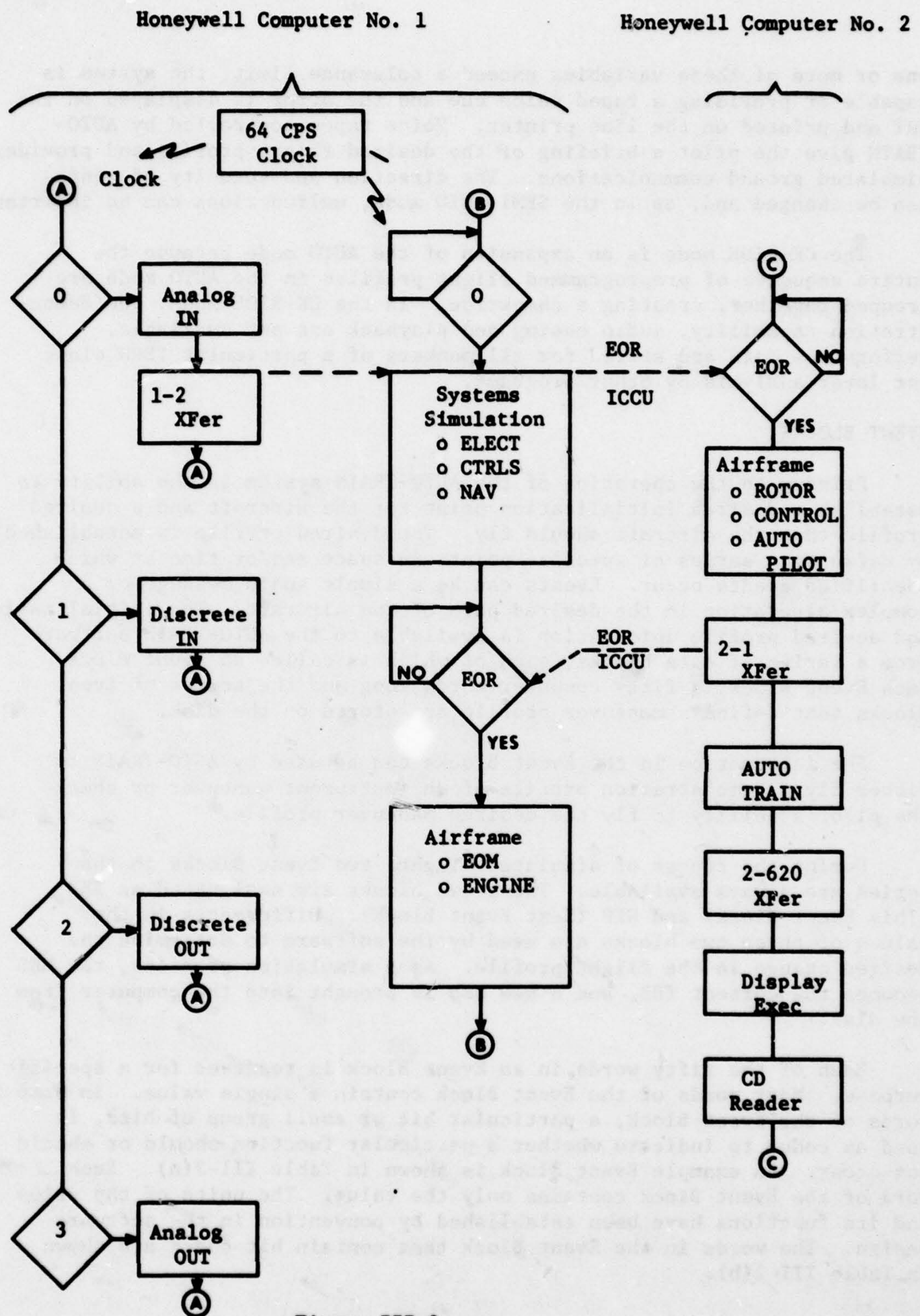


Figure III-2

Process and Data Flow in UH1FS Computer System
Numbers in diamonds are clock periods. Circled letters are the three basic processing chains.

one or more of these variables exceed a tolerance limit, the system is capable of providing a taped voice cue and the error is displayed on the CRT and printed on the line printer. Voice tapes controlled by AUTO-TRAIN give the pilot a briefing of the desired flight profile and provides simulated ground communications. The direction and velocity of winds can be changed and, as in the SEMI-AUTO mode, malfunctions can be inserted.

The CK-RIDE mode is an expansion of the AUTO mode because the entire sequence of preprogrammed flight profiles in the AUTO mode are grouped together, creating a checkride. In the CK-RIDE mode, the demonstration capability, audio cueing and playback are not available. Performance data are stored for all members of a particular IERW class for later analysis by other programs.

EVENT BLOCKS

Primary to the operation of the AUTO-TRAIN system is the ability to establish a desired initialization point for the aircraft and a desired profile that the aircraft should fly. The desired profile is established by defining a series of specific points in space and/or time at which identified events occur. Events can be a simple audio message or a complex alteration in the desired path of the aircraft. The initialization and desired profile information is available to the AUTO-TRAIN software from a series of data blocks, each of which is called an *Event Block*. Each Event Block is fifty computer words long and the series of Event Blocks that define a maneuver profile are stored on the disk.

The information in the Event Blocks can be used by AUTO-TRAIN to either fly a demonstration profile of an instrument maneuver or check the pilot's ability to fly the desired maneuver profile.

During the course of simulated flight, two Event Blocks in the series are always available. These two blocks are designated as TEB (This Event Block) and NEB (Next Event Block). Differences in the values of these two blocks are used by the software to determine the desired change in the flight profile. As a simulation proceeds, the NEB becomes the current TEB, and a new NEB is brought into the computer from the disk.

Each of the fifty words in an Event Block is reserved for a specific purpose. Most words of the Event Block contain a single value. In some words of the Event Block, a particular bit or small group of bits, is used as codes to indicate whether a particular function should or should not occur. An example Event Block is shown in Table III-2(a). Each word of the Event Block contains only the value. The units of the value and its functions have been established by convention in the software design. The words in the Event Block that contain bit codes are shown in Table III-2(b).

TABLE III-2(a). EXAMPLE EVENT BLOCK

Word #	Value	Unit	Function
WP 1	127436	Oct	A/P MODE
WP 2	000000	Oct	NAV MODE
WP 3	31.773	N.M	INIT LOC N
WP 4	35.937	N.M	INIT LOC E
WP 5	0	DEG	PITCH
WP 6	2.484	DPS	P/R LIM
WP 7	0	DEG	ROLL
WP 8	4.968	DPS	R/R LIM
WP 9	0	PSI	TQ PRESS CHNG
WP10	0	DEG	YAW
WP11	4.968	DPS	Y/R LIM
WP12	89.656	KTS	IAS
WP13	0.918	BAR	ACCEL LIM
WP14	3000	FT.	ALTD
WP15	499.687	FPM	CLIMB RATE
WP16	9.997	DEG	TRUE HEADING
WP17	620	NO.	EL/PHASE/TASK
WP18	100.000	MHZ	VHF FREQ
WP19	355	KHZ	ADF FREQ
WP20	9.997	DEG	MAG CRS TRK
WP21	2200	FT.	MIN ALTD
WP22	33.714	N.M	STA LOC N
WP23	36.351	N.M	STA LOC E
WP24	33.714	N.M	EXIT LOC N
WP25	36.351	N.M	EXIT LOC E
WP26	7163	LBS	GROSS WT
WP27	1430	LBS	FUEL WT
WP28	141	INC	CENTER OF G
WP29	59	DEG	OAT
WP30	29.889	IN.	BARO PRESS
WP31	20.006	DEG	WIND FROM
WP32	10.005	KTS	WIND SPEED
WP33	0	NO.	TURB LVL
WP34	27	NO.	MSG NO.
WP35	0	NO.	ADAPT LVL
WP36	100002	OCT	END MODE
WP37	0	SEC	END TIME
WP38	0	NO.	RESET SEG NO.
WP39	000000	OCT	ADAPT SCORE
WP40	0	NO.	MANEUVER NO.
WP41	0	NO.	SPARE
WP42	0	NO.	SEGMENT ID.
WP43	0	NO.	STATIC LVL
WP44	5	NO.	SOUND LVL
WP45	0	NO.	APU
WP46	000000	OCT	MALF IDENT MODE
WP47	0	SEC	MALF TIME
WP48	0		MALF EVENT
WP49	102401	OCT	DISPLAY MODE
WP50	8	NO.	DISPLAY CODE

TABLE III-2(b). DETAIL OF EVENT BLOCK WORDS
WHICH USE BITS FOR FUNCTION CONTROL

AUTO TRAINING

WORD 1, AIRCRAFT PERFORMANCE

Bit	Function
1	Eng Run
2	Slo Time
3	Initialize
4	Auto Rotate
5	Op Pedals
6	Op Lateral
7	Op Longitudinal
8	Op Collective
9	Fly Pitch not IAS
10	Fly Roll not Heading
11	Fly Power not Altd
12	Fly Yaw
13	Fly IAS not Pitch
14	Fly Altd not Power
15	Fly Heading not Roll
16	Make left turn

WORD 2, NAV MODE

Bit	Function
1	Turn Std Rate
2	Home to Location
3	Spare
4	Nav Intercept
5	Nav Track
6	To or Front Course
7	Fly VOR
8	Fly ADF
9	Fly ILS Localizer
10	Fly ILS Glideslope
11	Spare
12	
13	Task Start
14	Task End
15	Spare
16	Skip next Initialize

WORD 36, END CONDITIONS

Bit	Function
1	End on Initialize
2	End not Freeze
3	End on position
4	End on Track
5	End on Heading
6	End on Altitude
7	End on IAS
8	End on Yaw
9	End on Roll
10	End on Pitch
11	End on Torque Press
12	End on Rate of Climb
13	End on Rate of Turn
14	
15	Play Audio Message
16	End of Problem

WORD 39, SCORE CONTROL

Bit	Function
1	Score Track
2	Score Glide Slope
3	Score Altd
4	Score IAS
5	Score Heading
6	Score Roll
7	Score Pitch
8	Score Yaw
9	Score Rate of Climb
10	Score Rate of Trun
11	Score Torque Pressure
12	Spare Trim
13	Spare Min Alt
14	Spare Procedure
15	Spare Time
16	Spare

WORD 46, MALFUNCTION IDENT MODE

Bit	Function
1	Malfunction Impending
2	Event not Time Dependent
3	Malf Resetable
4	Spare
5	Spare
10-12	What Malf Work (-1)
13-16	Malf Sublist (-1)

Note: Sub one for input
Add one to output

WORD 49, DISPLAY MODE

Bit	Function
1	Display to Student Crt
5-8	What background Map (0-7)
9-16	What com)Scenario (1 to 36)

Knowing the structure of an Event Block, a flight profile can be produced by creating a series of Event Blocks with the necessary information. In the UH1FS system, this is done by support personnel using off-line support programs. Once a profile has been produced by creating a series of Event Blocks, it can be loaded in the UH1FS computer and used for training. This is the procedure that was used to create the flight maneuvers available in the AUTO mode.

Using Event Blocks to describe flight profiles is an integral part of the entire UH1FS software structure, and has been accepted as a design constraint for the creation of the automated performance measurement and grading system.

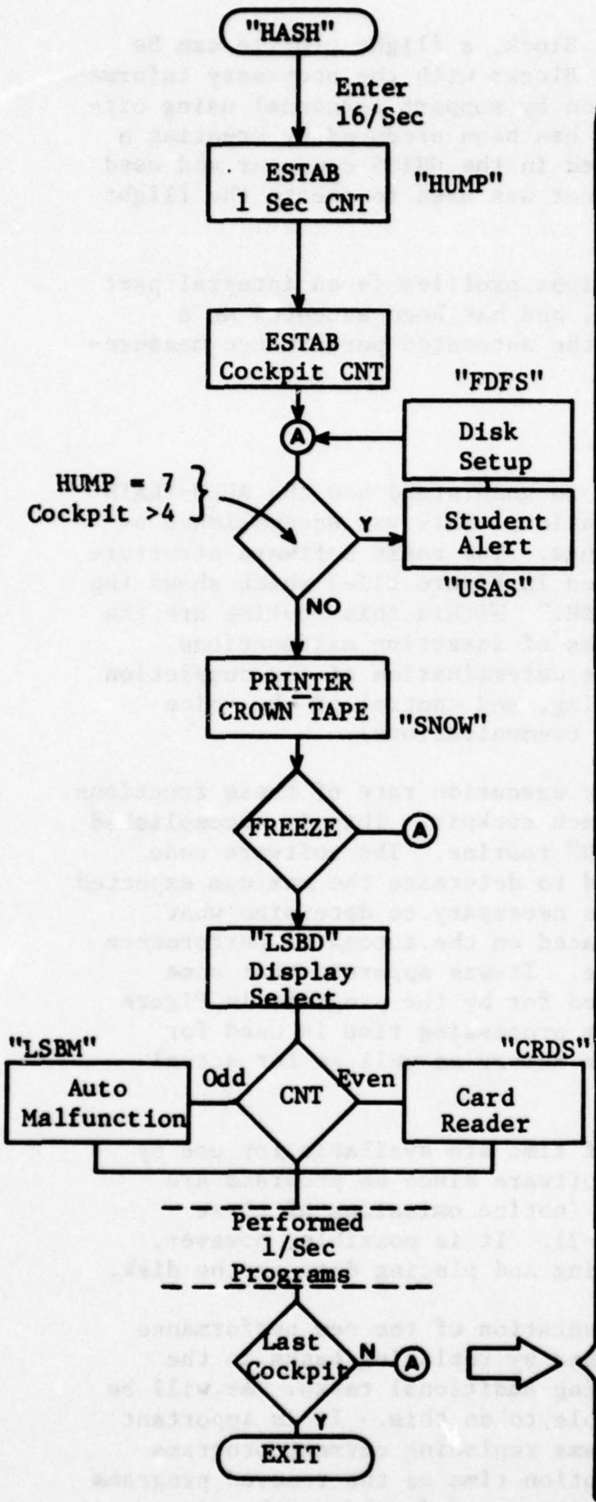
AUTO-TRAIN SOFTWARE TASKS

The next step in the analysis was to understand how the AUTO-TRAIN software worked during real-time simulation. This was accomplished by reviewing the AUTO-TRAIN program listings. The basic software structure of part of the AUTO-TRAIN is illustrated in Figure III-3 which shows the tasks of a software routine called "HASH." Within this routine are the software modules which perform the tasks of inserting malfunctions, controlling a flight demonstration, the determination of the completion of an Event Block, performance monitoring, and control of the voice messages (briefings, alerts and ground communications).

Figure III-3 also shows the cyclic execution rate of these functions. Most are performed once a second for each cockpit. This is accomplished by the use of counters within the "HASH" routine. The software code within each task of "HASH" was analyzed to determine the maximum expected execution time for each task. This was necessary to determine what execution time constraints would be placed on the automated performance measurement and grading system software. It was apparent that some execution time other than that accounted for by the programs in Figure III-3 must be reserved because computer processing time is used for retrieving and placing data on the disk memory as well as for actual execution of program instructions.

It appears that several periods of time are available for use by the proposed performance measurement software since no programs are allocated to time periods 6 - 9 and 13 (notice omissions of these numbers in right portion of Figure III-3). It is possible, however, that this time is reserved for retrieving and placing data on the disk.

This analysis implies that implementation of the new performance measurement system should be accomplished by replacing tasks in the "HASH" routines rather than simply adding additional tasks. As will be seen in the next section, it was possible to do this. It is important that the performance measurement programs replacing current programs should use approximately the same execution time as the removed programs since the timing of other program activities may depend on the time sequence of the "HASH" modules.



	Words	Time ≈µSec/ Cockpit
0 "HASP" END SER	561	170
1 "MSAC" Malfunction	139	100
2 "JYNX" Demonstration Controller	39	35
3 "HELP" Maneuver Detector	460	165
4 "JAPC" Demonstration Controller	678	676
5 "GROG" Set/Reset	66	70
10 "QUIZ" Adaptive Schedule	151	300
11 "PIMP" Performance Indicator	359	1.3
12 "WIND"	69	45
14 "PYMP" Procedure Ind	461	115
15 "USMC" Critiquer	222	306

FIGURE III-3

TRAINING ROUTINES

MEMORY ALLOCATION

It was important to determine how the memory in the Honeywell No. 2 computer was allocated. That is, it was necessary to know how much memory space each task required and exactly where it was located. The No. 2 Honeywell computer has a total of 24,576 words of memory. For a variety of reasons related to ease of programming, the memory is considered to be divided into 48 sectors of 512 words each. Table III-3 is a list of the 48 memory sectors and the software tasks which reside in them. The AUTO-TRAIN "HASH" is located in sectors 4 through 12. Software in these sectors manipulate data contained in other sectors. The data storage structure within these other sectors is as follows:

1. Variables associated with each of the four cockpits are located respectively in sectors 18 through 21. In addition, sector 17 is used for storage of data related to all of the cockpits.

2. The AUTO-TRAIN software that controls the printer uses sectors 46 and 47. In addition to the control software, the messages that can be printed are located here also.

3. Software and storage area for data that are transferred between computers uses sectors 22 and 23.

4. Sector 1 contains a list of pointers (addresses of memory) used by most of the software routines in the computer. In addition, sector 1 contains a 50-word buffer called ZTEM which is temporary storage that can be used by any of the software routines.

This completes the necessary analysis and description of the UH1FS system computer equipment and software.

IMPLEMENTATION DESIGN

This section describes the implementation design requirements for the automated performance measurement and grading system. Table III-4 summarizes the requirements of the measurement and grading system, characteristics of the existing UH1FS system which impact on the implementation design, and general features of the design which make implementation feasible without additional hardware. The implementation design of the performance measurement and grading system can be understood by considering it to have two major parts. The first part is the processes that occur during measurement and grading, i.e., the software tasks. The second part is the organization of tables, including Event Blocks which the software uses. These two parts are described below. Some minor features of the implementation design have been omitted to allow a clear presentation of the general implementation design concepts. These minor features, however, will become obvious to anyone involved in the actual implementation.

TABLE III-3. MEMORY SECTOR MAP FOR NO. 2 HONEYWELL COMPUTER. EACH SECTOR HAS 512 WORDS.

SECTORS	CONTENTS	SECTORS	CONTENTS
1	Registers Pointers Masks	24-29 30	Display Control 2-620 data Buffer
2	Main Executive (Ref Figure III-2)	31	On-line Trainer Debug
3	Minor Subroutines	32	Disk Write Check
4-12	Auto-train Routines (Ref Figure III-3)	33	Graphics control
13	Auto-train Disk	34-39	Rotor Tables
14-16	Rotor/Autopilot	40	Graphics Plotter
17	Parameter Buffer	41-44	Real-time Buffer
18-21	Parameter Storage (one sector per cockpit)	45	Real-time Loader
22	1-2 Data buffer Data shuffle	46-47	Printer Handler ASCII messages
23	2-1 Data Buffer Data Shuffle	48	Single Point Loader

Table III-4

Summary of Measurements and Grading Requirements, UH1FS System Constraints and Implementation Features For Automated Performance Measurement and Grading System

A. PERFORMANCE AND GRADING REQUIREMENTS

1. Compute 4-second running average for measurement and start/stop logic variables

2. Changing desired values for most variables

3. Three fixed tolerance levels for most variables

4. 15-second history of in or out of tolerance for most variables

5. Three fixed "time out of tolerance" levels for most variables

6. Score based on highest tolerance level exceeded plus percentage of variables exceeding tolerance level 1

7. Diagnostic text message for each measured variable with output organized by maneuver segment

B. UH1FS SYSTEM CONSTRAINTS

1. All 24,456 words of memory in number 2 computer is used for existing software

2. Memory organized in 512 word sectors

3. Little spare processing capability

4. Pervasive use of Event Block structure in system design

C. IMPLEMENTATION FEATURES

1. Reasonably limited number of measurement and start/stop logic variables (30 or less)

2. Heavy reliance on bit coding, i.e., use of bits or bit strings rather than full words (16 bits) to store most information

3. Simple logic with minimal numeric computations

4. Removal of UH1FS software modules not necessary during performance evaluation to provide memory space and processing time

5. Use of words or parts of words in Event Blocks for measurement system purposes

MEASUREMENT AND GRADING PROCESSES

Table III-5 shows the principal tasks that occur during performance measurement and grading. Figure III-4 is a schematic representation of the software processes that accomplish these tasks.

When a student pilot begins a session in the UH1FS the disk area where scoring and diagnostic information will be kept is cleared. At the beginning of each maneuver, the performance history and scoring tables are also cleared. Next, two Event Blocks are retrieved from the disk. The first Event Block contains information about the initial location of the aircraft, the variables which will be measured, and the desired values for those variables. The second Event Block is necessary so that the UH1FS system will know the expected progress of the flight profile and the measurement stop conditions.

Next, the measurement start/stop logic conditions are checked to determine if the conditions for starting or stopping measurement have been met. Assuming that measurement is ongoing, the next step is computation of the four-second running average values for all variables. Note that these averages are computed for all variables and not just the variables which are of current importance for scoring or start/stop logic conditions. The running average values are computed once per second. The average is computed by subtracting one-fourth of the current value of the average and then adding the new value. This computational procedure achieves the objective of smoothing the data and requires minimal storage (one word per variable) and execution time.

Next, two processes occur to determine if a variable has exceeded one or more of the tolerance levels. This determination occurs only for the variables currently being measured. First, the running average value of the variable is subtracted from the desired value. This difference is than compared successively to the values for the three tolerance levels. If a tolerance level is exceeded, a bit is set in the part of the History Table appropriate for the particular variable and the particular tolerance level exceeded.

Before an error is registered for scoring purposes, the running average value of a variable must exceed the tolerance level for a specified amount of time. This time-out-of-tolerance criteria is determined by checking to see if the History Table entries for a variable has a string of bits equal to or exceeding the time-out-of-tolerance requirement. Since all of the procedures being described here occur on a one-per-second basis, each bit in the History Table represents one second of information. The time-out-of-tolerance criteria is checked by comparing a mask (a bit string of the desired length with each bit set to 1) to the bits in the History Table. If all the mask bits match the bit string in the History Table, then the time-out-of-tolerance criteria have been met and the bit is now set in the appropriate place in the scoring table.

TABLE III-5

PRINCIPAL SOFTWARE TASKS FOR AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM

INITIALIZATION	o Check disk area for scoring information o Clear History and Score Tables o Retrieve first two Event Blocks from disk
CONTINUOUS, ONCE PER SECOND	o Check conditions for: Measurement start-stop Maneuver segment end Maneuver end o Retrieve next Event Block if required o Update 4-second running average for each variable o Subtract running average for each variable from desired value; then compare difference to the three tolerance levels in Standard Table o Set appropriate bits in History Table o Compare time-out-of-tolerance mask sequences to History Table for each variable; if a match is found set appropriate bit in Score Table
END OF MANEUVER SEGMENT	o Compute partial maneuver score o If Score Table full place on disk
END OF MANEUVER	o Compute maneuver score o Print out header information, score and diagnostic messages

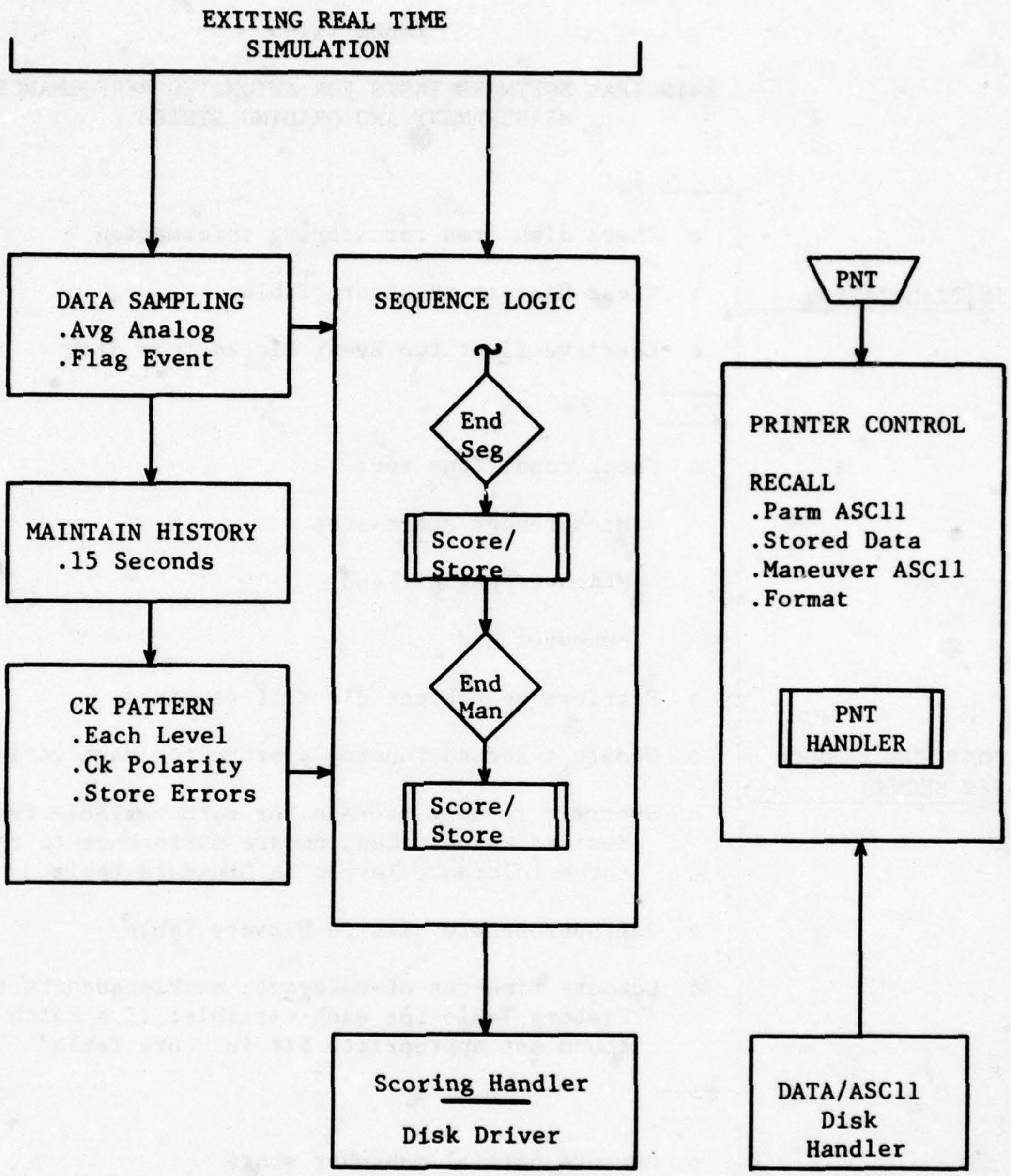


FIGURE III-4

Schematic Representation of the Automated Performance Measurement and Grading System Software Processes

Until the start/stop logic detects the end of a maneuver segment, the above steps are repeated. When the end of a maneuver segment is detected, a partial score for the maneuver is computed based on the information in the Score Table. Also, the diagnostic messages appropriate for each error registered in the Score Table are assembled and saved on the disk. At the end of the maneuver, the overall score is derived from the partial scores for each segment. The header information, maneuver score, and the diagnostic error messages are then printed.

DATA TABLES

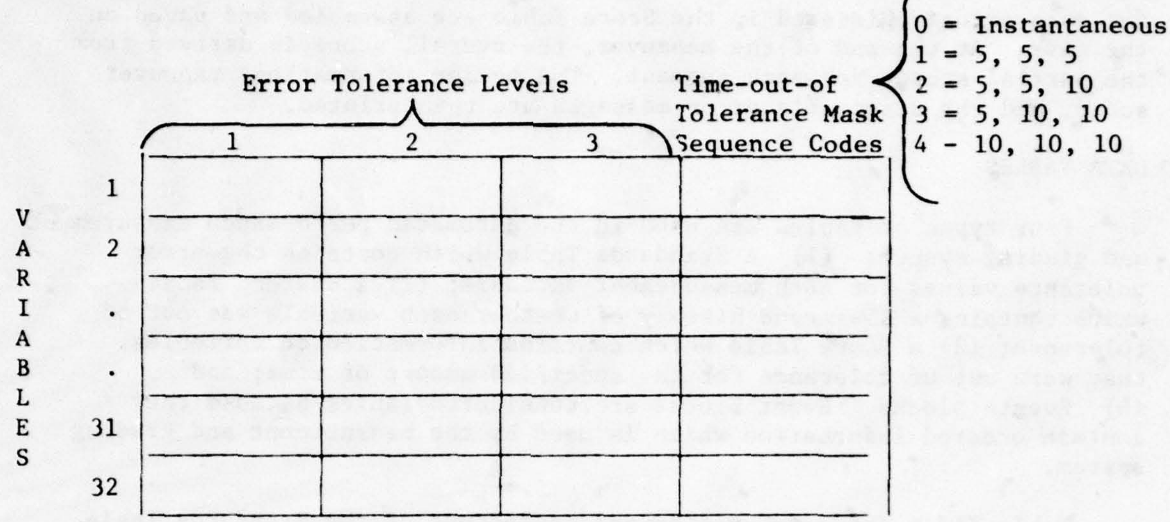
Four types of tables are used in the automated performance measurement and grading system: (1) A Standards Table which contains the error tolerance values for each measurement variable; (2) a History Table which contains a 15-second history of whether each variable was out of tolerance; (3) a Score Table which contains information on variables that were out of tolerance for the specified amount of time; and (4) Events Blocks. Event Blocks are considered tables because they contain ordered information which is used by the measurement and grading system.

Table III-6 shows schematic representations of the Standards Table and the History Table. Each of these tables can be considered to be a 4x32 word matrix. The dimension 32 occurs because information up to 30 variables can be preserved. Two of the words (16 and 32) are used for other purposes. The dimension 4 occurs because four computer words are required to store standards information for each variable. The first three words of memory associated with each variable in the Standards Table contain the error tolerance values. Note that these are not the desired values for a given variable, but the amount of error allowed for each of the three tolerance levels. The desired values come from the Event Blocks. For example, for altitude the three tolerance levels are 50, 100 and 200 feet with reference to the desired value. The first three words associated with the altitude variable would contain these three values. The fourth word associated with each variable is a code for the time-out-of-tolerance mask size associated with each variable. That is, this word does not contain the mask itself, but a code which specifies the time-out-of-tolerance necessary for each tolerance level before an error is registered. For scoring, the mask code and the three time-out-of-tolerance criteria which the mask code implies are shown in the upper righthand portion of Table III-6. The Standards Table is integral to the performance measurement software. Only one Standards Table is required for all four cockpits, since the standards are the same. Values in this table do not change during the course of performance measurement.

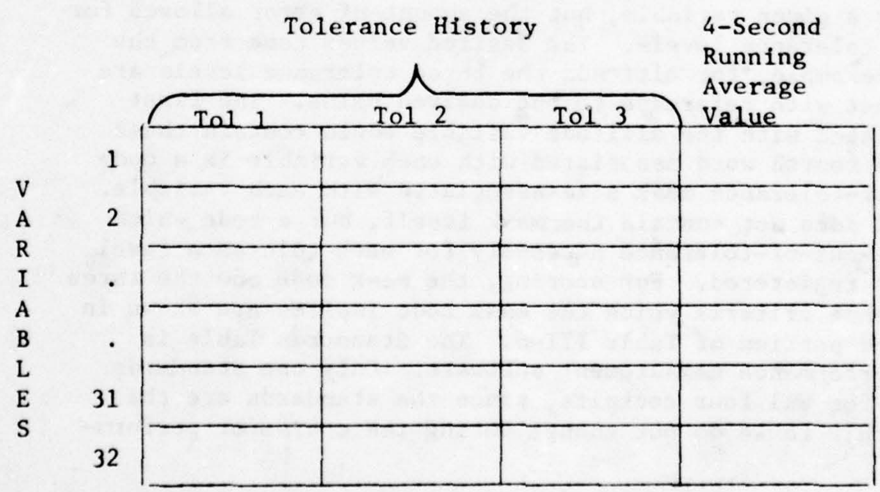
The History Table is organized similarly to the Standards Table but is used in a quite different way. The History Table may also be thought of as a 32x4 matrix of computer words. After the difference between the running average value and the desired value of a variable is compared to

TABLE III-6

SCHEMATIC REPRESENTATION OF ORGANIZATION OF STANDARDS TABLE AND HISTORY TABLE



a
Standards Table Organization
Total words required: 128
Note: Variable positions 16 and 32 are reserved.



b
History Table Organization
1 table per cockpit: Total words required (4 tables): 512
Note: Variable positions 16 and 32 are reserved; bit 16 of each word reserved for sign ($\pm$) polarity.

the three tolerance level values in the Standards Table, either a 1 or a 0 is placed in the first bit position (the lowest order bit) of the first three words in the History Table associated with a particular variable. For example, during a particular one-second cycle, if the running average of altitude exceeded the desired value by more than 50 feet but less than 100 feet, a 1 would be set in the first bit position of the first word associated with altitude and zeroes would be placed in the second and third word of the History Table. During successive one-second cycles of the measurement process, the bits in these first three words would be shifted over one place each cycle, and again, depending on whether a tolerance level is exceeded, a 1 or a 0 placed in the first bit position.

This cycle of setting the appropriate bits and shifting one place effectively maintains a historical record of whether each variable was within tolerance or exceeded one or more of the tolerance levels defined for it. Since the computer words are 16 bits long, the historical record for each variable can be a maximum of 16 seconds in length. Only 15 of the 16 available bits are used, and the 16th or last bit is used to record the sign, $\pm$, of the running average value of the variable with respect to the desired value. As the measurement process continues, the information in bit position 15 is lost after each shift.

The fourth word associated with each variable in the History Table is the actual running average value of the particular variable. It is not absolutely necessary that the running average value be part of the History Table, but it is a convenient location for it.

The History Table is an extremely compact method for maintaining information on the degree of error for each variable relative to its desired value. Only 128 words of memory are required for each historical table. Four tables are required, one for each cockpit, for a total of 512 words of memory. If actual values were preserved, rather than a bit code, the amount of storage required would be 16 times greater, i.e., 8,192 words.

SCORE TABLE

Scoring information is derived by applying the appropriate time-out-of-tolerance mask sequences to the History Table. If a match is found, an error score is registered and saved in the Score Table. Table III-7 shows the organization of the Score Table. The first three words contain identifying information that will be used when the maneuver score and diagnostics are printed out. Successive copies of the Score Table are preserved on the disk for each of the four cockpits. Therefore, the header information will also be useful to separate the scoring information for a particular student from that of others.

Each Score Table is a maximum of 30 words in length. Scoring information from up to three segments of a maneuver can be recorded before it is placed on the disk. Since all maneuvers involve more than

TABLE III-7

SCORE TABLE ORGANIZATION

Maneuver Header and Score Information (3 words)	Cockpit Identification
	Date
	Maneuver Score
Segment Score Information (9 words)	Maneuver Identification
	Segment Identification
	Segment Score
	Variables 1-5 Score
	Variables 6-10 Score
	Variables 11-15 Score
	Variables 16-20 Score
	Variables 21-25 Score
	Variables 26-30 Score
Segment Score Information	9 Words (As Above)
Segment Score Information	9 Words (As Above)

Variable Score Codes (3 bits)
000 = Within Tolerance
100 = Fatal Error
p 01 = Tol. Level 1 Exceeded
p 10 = Tol. Level 2 Exceeded
p 11 = Tol. Level 3 Exceeded
p is sign (±) polarity

2 score tables per cockpit (for buffering); up to three segments per task before placement of disk.

Total words required (4 cockpits) = 240

three segments, several copies of the Score Table will have been generated before the end of a maneuver.

The scoring information for each segment also is bit coded. It can be seen in Table III-7 that each word of the segment-score group contains scoring information for five variables. The codes for each variable and their meaning are shown in the right-most portion of the table.

The Score Table can be thought of as a buffer, since the information placed in the table is stored only temporarily in memory, and when the table is full, it is placed on the disk. It is always possible that the performance measurement system may attempt to write information in the Score Table at the same time that it is being transferred to the disk. Since these two operations cannot occur simultaneously, this conflict is avoided by having two Score Tables available for each cockpit at the same time. Thus, while one table or buffer is being placed on the disk, the performance measurement system can place information in the other table. This procedure is a common computer software technique known as double buffering.

USE OF EVENT BLOCKS

Event Blocks, described earlier, are an important part of the UH1FS system. Event Blocks can be considered as a series of tables which are retrieved as necessary from disks to provide information to both the UH1FS simulation processes and also to the performance measurement system. Since certain software modules will be deleted in order to implement the performance measurement system, the Event Block words that these deleted modules would use can be used to provide information to the performance measurement system. The standard structure of the Event Blocks makes provision for aircraft variables such as aircraft heading, airspeed, etc. When the performance measurement system is used, the Event Block locations for aircraft variables will contain the desired values. Thus, when new desired values change at different points in the flight maneuver, the new desired values are available from the next Event Block.

The performance measurement system also uses other words in the Event Block for measurement start/stop logic functions and determining which variables are to be measured and scored. Table III-2(a) shows the system use of the Event Block words other than those used for storing desired values.

ADDITIONAL FEATURES

Some additional features of the automated performance measurement and grading system require explanation. The 15-second History Table for each variable is necessary because the start/stop logic tracks the pattern of change in a variable to determine when measurement is to start or stop. When a start or stop condition is confirmed, the data for the measured variables over the determination period either will be included for scoring if measurement is to start or discarded if measurement is to stop. The History Table preserves these data without affecting scoring until the start or stop of measurement decision has been made. The History Table is important for a second reason. Since it is a record of the time-out-of-tolerance states for each variable, it is the base for application of the time-out-of-tolerance mask sequences to determine if an error should be recorded in the Score Table.

Fatal errors terminate the measurement of performance and no score is printed. Diagnostics up to the fatal error segment, however, are printed. The fatal error tolerances that change will be partially in the Event Blocks (radio frequencies, etc.), and those that are constant for all maneuvers (airspeed, bank angle, etc.), will be in a small table integral to the performance measurement and grading software.

In Table III-2(b), certain bits of the bit-coded words were not defined. Their intended use is as follows: bit 12 of word 2 will be used to distinguish between the end of a measurement segment and a maneuver segment. The bits of word 36 will have the same general functions as shown in Table III-2(b), but the exact definitions will depend upon actual implementation. Bit 14 is reserved for the contingency that more than one start/stop logic condition may be used to end a measurement segment. In this event, bit 14 would indicate whether to start or stop measurement if one of several conditions is true (OR function) or whether all defined conditions must be met before measurement starts or stops (AND function). The first 15 bits of word 39 and word 41 (a spare word in the Event Block structure) will be used to indicate which variables are to be scored during a measurement segment. Bit 16 of each word will indicate whether the History Table should be cleared at the end of a maneuver segment.

REQUIRED SOFTWARE CHANGES

The implementation requires modification of most of the software shown in Figure III-3. The software modules that must be dropped, modified or added for the automated performance measurement and grading system are listed in Table III-8. In addition, all of the remaining software within the No. 2 Honeywell computer must be reviewed to eliminate indirect references to specific memory locations within the AUTO-TRAIN system because the modifications will change the absolute memory addresses of many of the software modules.

During implementation, certain other software in the No. 2 Honeywell computer must be examined and modified if necessary to allow for the addition of the new software. The principal areas of concern are the data movement routines, the memory address pointers located within sector number 1, and the sectors reserved for the aircraft variables for each cockpit (sectors 18-21). It is expected that the History Table will use sector 16 and that the Standards Table will use the last half of sector 22. These sectors presently are used by routines within the

TABLE III-8

REQUIRED SOFTWARE MODIFICATIONS FOR AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM

ELIMINATE CODING (1618 lines)	MODIFY CODING (2841 lines)	ADD CODING (250 lines)
"WIND" (69) Wind Adaptive Control	"HASH" (124) Auto Trainer Exec Modify to eliminate calls to deleted routines and include calls to new routines	Data Sample/smooth (106 lines)
		History (48 lines)
"QUIZ", "QUIP" (151) Adaptive Controller	"JYNX", "JAPC" (744) Demonstration Controller Review logic to insure newly defined buffers are compatible	Pattern History (96 lines)
"PIMP", "PYPE" (359) Performance Indicator		
"PYMP" (461) Procedural indicator	"HASP","HELP" (1021) End sequence detector modify to incorporate newly defined logic and scoring process	
"USMC", "USAF" (401) Audio alert controller	"FDFS","XDFD" (511) Disk Handler Modify to incorporate new output	
"CSDR" (177) Card reader controller	"XHCP" (441) Hard copy handler modify to new design and place output in background mode	

AUTO-TRAIN system and, thus, are available for the performance measurement and grading system. The text messages for the diagnostic error information will use sectors 46 and 47. If additional space is required for this purpose, it is available in sectors 41 through 44.

The software for controlling the card reader is deleted. The card reader would be of very minor value to the performance measurement and grading system and it has, therefore, been dropped in the interest of providing more memory space for the new software.

USE OF THE AUTOMATED PERFORMANCE MEASUREMENT AND GRADING SYSTEM

The system design requirements include the possibility of two modes of use, the AUTO mode and the CK-RIDE mode. In the AUTO mode, only the header information in the maneuver grade score would be printed. In the CK-RIDE mode the header information, maneuver score and complete diagnostics will be printed.

MODIFICATION OF PERFORMANCE CRITERIA

After implementation and some experience with the automated performance measurement and grading system, it may be desirable to change the performance criteria. This is easily done by modification of the Standards Table and/or the time-out-of-tolerance mask lengths. Since these are integral to the performance measurement software, it will be a simple matter to change the criteria to any values desired.

CHAPTER IV

SYSTEM TESTING, USER HANDBOOK, SYSTEM EXPANSION AND GENERAL CONCLUSIONS

TESTING

Two tests of the automated performance measurement and grading system are described in this section: (1) acceptance testing and (2) utility testing (criteria and validity/reliability).

Acceptance testing addresses the question, "Does the system work as specified by the design requirements?" Utility testing addresses the question, "Does the system measure and grade instrument flight performance in a meaningful way, and does it do so in a consistent manner?"

ACCEPTANCE TESTING

The purpose of the acceptance test is to demonstrate that the performance measurement and grading system correctly detects performance errors at the proper time, that a grade is correctly determined, and that the printout at the end of a maneuver is correct in all respects. Essentially, the acceptance test is proof that the software operates in the manner specified by the performance measurement design.

To determine the correct operation of the system, it is necessary to produce, independent of the measurement system, a time history of all the variables that are measured. These independent data can then be compared to the output of the performance measurement and grading system.

How the independent data will be recorded and printed in a manner that allows easy comparison to the performance measurement output is part of the implementation design work. It is suggested, however, that the recording occur by saving on the disk (or an auxiliary tape unit), the running average values of the measured variables, sampled once per second, along with the performance measurement data. The software necessary to accomplish this can be initially included in the measurement software and removed after completion of the acceptance test.

The implementation designer will have to determine how, and in what form, the recorded data will be printed to allow the visual comparison of the two sets of data. The most likely approach is to reduce and print the data offline on another computer system.

As a minimum, the independent data should allow for checking of the operation of each individual measure, each start-stop logic condition, correct error level (tolerance level) detection, correct grade computation, and correct printing of the diagnostic error messages.

Potentially, there are two possible ways of testing the performance of the measurement system. The first is to use the demonstration flight features (Auto Pilot) of the UH1FS to produce a flight profile with and without particular errors. The second way is to have a highly proficient pilot fly the maneuvers and commit selected errors at specific times. Each method has advantages and disadvantages.

Employment of the Auto Pilot assures that the flight profile will be flown as specified. Programming a flight profile for the Auto Pilot, however, is not a simple task. Also, because of the design of the UH1FS control system, the Auto Pilot will try to compensate for certain kinds of errors. For example, the Auto Pilot cannot be forced to fly out of trim. It will automatically attempt to bring the aircraft back to proper trim. Compensation features are deeply embedded in the software system and cannot be disabled easily.

Use of a skilled pilot is the simplest means for having a desired flight profile flown. It obviates the need for programming of the Auto Pilot and allows flexibility in determining what sort of profile should be flown. The disadvantage is that the pilot may make errors or fail to commit the desired errors required for the test.

It is suggested that the acceptance test occur after all of the software for the six maneuvers has been implemented. It may be tempting to test and accept the software on a maneuver-by-maneuver basis. Since problems may occur due to software interactions when an entire measurement system is implemented, it is more prudent to schedule the acceptance test only after complete software development.

An implicit requirement of the implementation of the automated performance measurement system is that its processing and memory requirements not interfere with the basic operation of the UH1FS flight control software. Part of the acceptance test should include a means of demonstrating this non-interference. The method for the non-interference demonstration can be specified only during the implementation design work, since it will depend heavily upon the characteristics of the performance measurement software.

Acceptance Test Plan

At the beginning of the implementation work a detailed acceptance test plan should be developed jointly by the Army COTR and the implementation contractor. The acceptance test plan, as a minimum, should require that:

(1) All six automated maneuvers will be tested.

(2) The specific items to be tested within each maneuver will be stated.

(3) The number of situations, i.e., the number of instances of each measure and the tolerance levels of each measure that will be demonstrated during acceptance testing will be stated.

(4) The correct operation of each start-stop logic element in the proper sequence for each maneuver will be proven

(5) The nature of the supporting information that will be used to verify correct operation of the measures and start-stop logic will be specified

(6) The proper printing of the output, including the header, grade and diagnostic information will be demonstrated

(7) Proof of non-interference of the performance measurement software with the basic UH1FS flight control software will be demonstrated.

(8) That the entire system can be utilized by operational personnel, i.e., a student pilot or an IP will be shown.

(9) Any software developed for acceptance test purposes will be documented and will be a deliverable item with the performance measurement system software documentation.

(10) An outline of activities and a realistic schedule for conduct of the acceptance test will be prepared.

The acceptance test demonstrates that the implemented software operates according to the design specifications. Other tests will occur during the course of implementation that do not relate specifically to acceptance testing. For example, it is within the scope of the implementation work, prior to acceptance testing, to demonstrate that internal computational and logic routines operate properly and that the system is protected against timing errors, noisy data, etc.

UTILITY TESTING

The automated performance measurement and grading system design and implementation design have been arrived at analytically. The designs were kept as simple and straightforward as possible in the hope that a practical and useful instrument flight performance measurement system would result. Ultimately, however, it will be necessary to conduct empirical testing for refinement of the system. After completion of the acceptance test, a program of empirical work should begin to determine the validity and reliability of the automated performance measurement and grading system.

Validity means that the grade produced is an accurate expression of instrument flight performance. Reliability means that a pilot with a given performance ability will receive the same grade each time his performance is measured by the system. The performance measurement system would have very little value if every pilot tended to receive the same grade regardless of his performance ability or the grade received fluctuated markedly even though there is no reason to believe that the pilot's ability has changed.

The utility testing should be considered to involve two stages: (1) tolerance criteria testing; and (2) validity and reliability testing.

Tolerance Criteria Testing

The initial empirical work should concentrate on refining the tolerance levels and the means of producing the composite grade for a maneuver. As discussed earlier, many of the tolerance levels specified were based on SME opinion. Collecting data on pilots of known skill levels, i.e., low experience student pilots, high experience student pilots, rated pilots and IPs with extensive experience, should allow development of realistic tolerance levels.

The tolerance levels currently suggested appear reasonable, but until they can be verified by actual performance data, decision makers cannot be confident that the decisions they make based on the unconfirmed performance criteria are justified. Once the tolerance criteria have been validated, pilot training and evaluation can be based on realistic empirically derived criteria rather than criteria that have been chosen arbitrarily or based on past experience.

The amount of data that might be required for tolerance criteria testing is difficult to predict without some preliminary data on pilot-system behavior. It is not known whether the chosen tolerances will produce a range of performance scores which adequately discriminate between successful and unsuccessful maneuver performance with useful precision. By the time acceptance testing is completed, the measured pilot-system behavior will be better known and the amount of testing required to have confidence in the tolerance criteria will be more predictable. At this time, however, it is only possible to estimate a minimum and maximum data collection plan for validity and reliability testing.

As a minimum, two groups of pilots would be required: (1) highly experienced pilots (IPs), and (2) pilots of very low experience (IERW students) to expose the system to the range of performance that is expected. An absolute minimum of three pilots in each group would fly all six maneuvers one time in one or two simulator sessions. About twelve hours of simulator data collection time time would be required.

As a maximum, four groups of pilots would be used: (1) IPs; (2) rated pilots; (3) IERW "near-graduates;" and (4) low time students. A maximum of five pilots in each group would fly all six maneuvers for a maximum of three replications. About 120 hours of simulator data collection time would be required. Thus, the boundaries of data collection for tolerance criteria testing are between 12 hours and 120 hours of simulator time, and between 6 and 20 pilots of varied experience levels. In addition to subject pilot requirements, two or three instructor pilots would be needed to score student performance. A comparison of IP scoring and the measurement system output should indicate the adequacy of the specified tolerance criteria.

It is important to note that the purpose of this testing is to insure that the tolerance criteria are set to levels that will produce a discriminable range of scores when actual performance quality varies. Because the whole measurement system is predicated on the validity of tolerance criteria, the criteria themselves have to be examined empirically before examining the validity of the results of the measurement, i.e., the maneuver grading. The test plan must accommodate the stop of data collection and changing tolerance criteria as it becomes obvious and necessary to do so. When the investigators are satisfied that the tolerance criteria produce a discriminable range of scores, the validity testing work can begin.

Validity and Reliability Testing

Validity of the performance measurement and grading system can be defined in several ways: (1) ability of the measures to discriminate between aviators of varying levels of performance (as defined by their flight experience and resulting performance scores); (2) the correlation between the judgments (grades) of IPs and the grades produced by the measurement system; (3) the degree of instructor confidence in the system output based on their observation of the maneuver and the system output (after they have manually scored the maneuver); and perhaps (4) the ability of the measurement system to predict final checkride grades of those student aviators who were tested.

A nominal but formal test plan for these kinds of validity tests would require the following: three groups of approximately 16 aviators each (group 1 - low time students; group 2 - near graduate students; and group 3 - highly qualified experts) would fly a minimum of three replications of each of six maneuvers. Only three maneuvers would be flown at one time by any aviator (to reduce the possible effects of fatigue) in a one-hour test session. Three maneuvers would be flown on two successive days by each aviator. Thus, each aviator would require six hours of simulator testing time. Overall, 288 hours would be required over a period of approximately 18-20 weeks based on a test schedule using four hours per day, four days per week. This is only a "nominal" plan because student flow and accessibility have to be considered before the final plan is developed.

Reliability testing is implicit in the validity test plan. The replications of the maneuvers by the pilots will provide sufficient information to determine the reliability of the measurement and grading system.

A test plan which requires less student and simulator time resources may be possible, depending upon the data which result from acceptance testing and tolerance criteria testing. Data collection economies may be possible if tolerance criteria testing data may be used also for validity test purposes. Thus, the above validity test plan requirements must be considered tentative until the completion of tolerance criteria testing.

USER HANDBOOK

It is necessary that a handbook be developed which explains to the pilot-user the background and use of the automated performance measurement and grading system. The handbook will definitely be necessary since, in addition to other reasons, the implementation of the automated performance measurement system will require the removal of the software section that controls the automatic voice tape maneuver briefing. Therefore, the maneuver requirements must be given to the pilot in written form.

The handbook should be part of the overall implementation development and include sections on: (1) the general philosophy of the automated performance measurement system so the student pilot is aware of how his performance is being assessed; (2) a description of each measure, including tolerance and timing requirements to aid in interpreting the diagnostic messages; (3) the grading concept; and (4) a description of each maneuver, including the initial conditions, the performance requirements, the correct radio settings, and a schematic diagram of the desired maneuver flight profile.

The maneuver descriptions should include a clear statement of the requirements that are arbitrary for the sake of performance measurement, i.e., the requirement to parallel an outbound approach course for one minute, make all climbs and descents at 500 fpm, and track all outbound courses for two minutes; (5) a table describing how to invoke or "dial up" each maneuver and modes (AUTO or CK-RIDE) and the options available during the AUTO mode.

In other words, the purpose of the handbook is to give the pilot complete understanding of the measurement system, how his performance will be assessed and graded, and how to use the system.

EXPANSION OF MEASUREMENT SYSTEM

The automated performance measurement system was specifically designed to grade performance on six Basic and Advanced Instrument maneuvers. The measures and principles of application, however, are general and can be expanded easily to other instrument maneuvers. Also, based on the previously described methods used to develop the measure set, additional required measures can be developed. The only constraint is the capacity of the UH1FS hardware and software to accommodate the extensions.

At some future time it may be desirable to expand the number of maneuvers for which performance can be assessed. During the maneuver analysis phase of this work, it became apparent that there are several types of instrument flight maneuvers that would be a useful part of the automated Advanced Instrument maneuver package. Specifically, a VOR or NDB holding maneuver appears to be desirable. The holding at an intersection is a fairly difficult maneuver for a student pilot, since he must assess both the VOR and ADF readings to interpret his position. Holding over a single beacon would be somewhat less difficult and may be useful for training purposes.

Another maneuver which would probably be of great utility for Army aviators is a tactical instrument approach. Tactical instrument flight is of particular importance to Army aviators and the UH1FS would be an excellent means for both training and performance measurement on tactical instrument inflight navigation and approaches.

In addition to maneuvers that have different performance requirements, it may also be useful to develop variations on the standard maneuvers now included in the automated Advanced Instrument maneuver package. This would insure that a student pilot does not simply learn a specific approach but can apply the same skills and knowledges to a variety of standard approach and holding maneuvers.

CONCLUSIONS

1. Design requirements for an automated performance measurement system for instrument flight maneuvers in a UH1FS have been developed analytically. The system is based on final criteria referenced performance and measurement of the aircraft variables which are the critical indicators of performance.

2. The performance measurement system will produce a composite grade for each instrument maneuver that is compatible with the concurrently developed inflight performance assessment system. Diagnostic error messages which reflect the magnitude of error of each measured variable within each segment of maneuver also will be produced by the system.

3. Implementation design requirements for the automated performance measurement and grading system have been developed which have minimal processing and memory needs. They are compatible with existing UH1FS control software and no additional hardware is required.

4. The automated performance measurement system should be implemented and, after acceptance test completion, subjected to empirical utility testing. Particular attention should be paid to the tolerance levels specified for each measure.

5. A handbook which describes the purpose, function, use and interpretation of the output of the automated performance measurement and grading system should be developed concurrently with implementation of the system.

REFERENCES

1. USAAVNC, *Rotary Wing Instrument Guide*, Fort Rucker, AL, Feb 1977.

2. USAAVNC, DUFT, *Rotary Wing Basic Instrument Flight*, informal publication, Fort Rucker, AL, Oct 1976.

3. FM 1-5, *Instrument Flying and Navigation for Army Aviators*, DA, 1976.

4. AR 95-63, *Army Aviation Standardization and Instrument Program*, DA, 1976.

5. DOD Flight Information Publication (Terminal), *Low Altitude Instrument Approach Procedures*, Vol. 6, South Central United States, The Defense Mapping Agency Aerospace Center, St. Louis Air Force Station, MO, 1977.

6. USAAVNC Regulation 350-16, *The Uniform Flight Grading System*, (with changes), DA, 1970.

7. *op. cit.*, Ref. 1.

8. USAAVNC, *UH-1 Flight Simulator Handbook*, DA, 1977.

9. Childs, Jerry M. *Inflight Performance Assessment*, Interim Report, Manned Systems Sciences, Inc., Fort Rucker, AL, 14 November 1977.

10. *op. cit.*, Ref. 1.

11. *op. cit.*, Ref. 8.

12. *op. cit.*, Ref. 1.

13. *op. cit.*, Ref. 2.

14. *op. cit.*, Ref. 3.

15. *op. cit.*, Ref. 4.

16. *op. cit.*, Ref. 5.

17. *op. cit.*, Ref. 9.

18. *op. cit.*, Ref. 9.

APPENDIX

MANEUVER DESCRIPTIONS AND PERFORMANCE MEASUREMENT REQUIREMENTS

This appendix contains six sections, one for each of the six automated Basic and Advanced Instrument maneuvers implemented in the UH1FS, for which a performance measurement design has been developed. The six maneuvers are: (1) Climbing and Descending Turns; (2) NDB Approach; (3) VOR Approach; (4) ILS Approach; (5) Localizer Backcourse Approach; and (6) Holding at Intersection.

Each maneuver section contains a general description of the maneuver, a short discussion, a listing of the maneuver segments, the performance requirements and common errors associated with each segment, a figure illustrating the maneuver profile and segmentation, the initial conditions at the beginning of the maneuver, a tabular summary of the measurement start-stop logic and measures applied during each segment, and a tabular summary of the fatal errors which will cause termination of performance measurement for each maneuver.

The development of the maneuver segmentation, the measurement start-stop logic, and the measures were described in Chapter II.

CLIMBING AND DESCENDING TURNS

A. General Description

The climbing and descending turns problem requires the aviator to execute a series of heading changes and altitude changes simultaneously. The time required for each segment is determined by the required altitude change. That is, the heading change is always completed before or at the same time the altitude change is completed. All turns are required to occur at the standard rate of 3° per second and all altitude changes at 500 feet per minute. Each segment of the maneuver is separated by a 30-second segment of straight and level flight. The series of climbing and descending turns is executed without regard to any fixed geographic location.

B. Discussion

The climbing and descending turns maneuver is considered to be the most difficult Basic Instrument maneuver, since it requires the coordination of all flight controls. It is the last in a sequence of progressively more demanding automated Basic Instrument maneuvers in the UH1FS. If the aviator can perform the climbing and descending turns maneuver in a satisfactory manner, it is a virtual certainty that he can perform the preceding maneuvers of level turns and straight climbs and descents. Each of the Basic Instrument maneuvers consists of three phases: (a) a demonstration phase, where the control computer flies the aircraft through the maneuvers and an automatic voice tape describes the salient features to the pilot;

(b) a guided practice phase where the pilot takes control of the aircraft and performs the maneuver segments directed by the voice tape, which also gives hints about how to perform the maneuver; and (c) adaptive practice phase, where the pilot flies the maneuver, and, depending on his performance, the turbulence level is steadily increased or decreased, making the flying task either more difficult or easier, depending on the proficiency demonstrated by the pilot.

Climbing and descending turn maneuvers which have been specified for automated performance assessment are the same as those used in the demonstration. A requirement for 30 seconds of straight and level flight between each climbing or descending turn has been added to obtain information on the pilot's ability in a steady state. The performance data obtained during the straight and level segments will be of some possible diagnostic value for those pilots who do not perform well in the climbing and descending turns. If the pilot is able to perform well in the straight and level segments, it is an indication that the proficiency problem is confined to the execution of turns and descents. On the other hand, if the pilot does not do well on the straight and level segments, it will indicate that he is not proficient in any type of basic aircraft control under instrument conditions.

The last segment of the maneuver is a level turn. Again, this will be of diagnostic value similar to that obtained during straight and level flight. Depending on his performance during this segment, it will be evident whether his basic aircraft control under instrument conditions is deficient or whether he has a specific difficulty with performing climbing and descending turns.

C. Maneuver Segmentation (See Figure 1)

1. Straight and Level

a. Performance Requirements

(1) Maintain heading (330°)

(2) Maintain altitude (2000 ft)

(3) Maintain airspeed (90 K)

b. Common Errors

(1) Failure to establish normal cruise airspeed (incorrect power setting)

(2) Heading errors

(3) Altitude errors

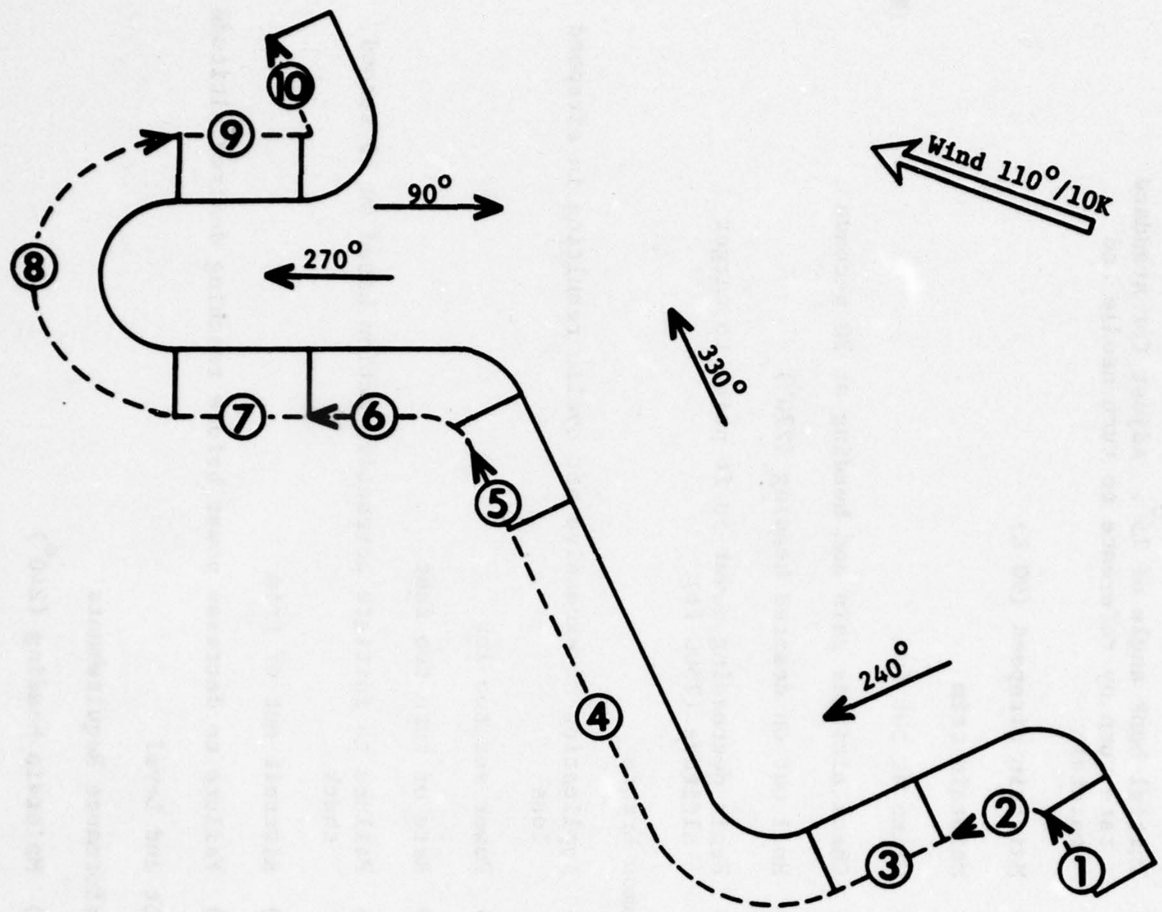


Figure 1

Schematic Representation of Climbing and Descending Turns Maneuvers (Maneuver Segments are Shown by Dashed Line. See Text for Segment Names.)

2. Climbing Left Turn

a. Performance Requirements

(1) Initial power setting 5 psi above cruise (26 + 5)

(2) Initial bank angle of 15^{o}. Adjust for standard rate turn by reference to turn needle and maintain

(3) Maintain airspeed (90 K)

(4) Maintain trim

(5) Climb at 500 fpm

(6) Check altitude gain and heading at 30 seconds

(7) Roll out on desired heading (270^{o})

(8) Begin decreasing power 50 ft prior to target altitude (2500 ft)

b. Common Errors

(1) Application of excessive aft cyclic resulting in airspeed loss

(2) Power set too low

(3) Rate of turn too fast

(4) Failure to initiate corrective action based on 30 second check

(5) Aircraft out of trim

(6) Failure to decrease power before reaching desired altitude

3. Straight and Level

a. Performance Requirements

(1) Maintain heading (240^{o})

(2) Maintain altitude (2500 ft)

(3) Maintain airspeed (90 K)

b. Commor Errors

(1) Failure to establish normal cruise airspeed (incorrect power setting)

(2) Heading errors

(3) Altitude errors

4. Descending Right Turn

a. Performance Requirements

(1) Initial power setting 5 psi below cruise (25 -5)

(2) Initial bank angle of 15°. Adjust for standard rate turn by reference to turn needle and maintain

(3) Maintain airspeed (90 K)

(4) Maintain trim

(5) Descend at 500 fpm

(6) Check altitude loss and heading at 30 seconds

(7) Roll out on heading (330°)

(8) Begin increasing power 50 ft before reaching desired altitude (1500 ft)

b. Common Errors

(1) Power set too high

(2) Rate of turn too slow

(3) Failure to initiate corrective action based on the 30 second check

(4) Aircraft out of trim

(5) Failure to increase power before reaching desired altitude

5. Straight and Level

a. Performance Requirements

(1) Maintain heading (330°)

(2) Maintain altitude (1500 ft)

(3) Maintain airspeed (90 K)

b. Common Errors

(1) Failure to establish normal cruise airspeed (incorrect power setting)

(2) Heading errors

(3) Altitude errors

6. Climbing Left Turn

a. Performance Requirements

(1) Initial power setting 5 psi above cruise (26 + 5)

(2) Initial bank angle of 15^{o}. Adjust for standard rate turn by reference to turn needle and maintain

(3) Maintain airspeed (90 K)

(4) Maintain trim

(5) Climb at 550 fpm

(6) Check altitude gain and heading at 30 seconds

(7) Roll out on desired heading (270^{o})

(8) Begin decreasing power 50 ft prior to target altitude (2000 ft)

b. Common Errors

(1) Application of excessive aft cyclic resulting in airspeed loss

(2) Power set too low

(3) Rate of turn too fast

(4) Failure to initiate corrective action based on 30 second check

(5) Aircraft out of trim

(6) Failure to decrease power before reaching desired altitude

7. Straight and Level

a. Performance Requirements

(1) Maintain heading (270^{o})

(2) Maintain altitude (2000 ft)

(3) Maintain airspeed (90 K)

b. Common Errors

(1) Failure to establish normal cruise airspeed (incorrect power setting)

(2) Heading errors

(3) Altitude errors

8. Descending Right Turn

a. Performance Requirements

(1) Initial power setting 5 psi below cruise (26 -5)

(2) Initial bank angle of 15^{o}. Adjust for standard rate turn by reference to turn needle and maintain

(3) Maintain airspeed (90 K)

(4) Maintain trim

(5) Descent at 500 fpm

(6) Check altitude loss and heading at 30 seconds

(7) Roll out on heading (90^{o})

(8) Begin increasing power 50 ft before reaching desired altitude (1500 ft)

b. Common Errors

(1) Power set too high

(2) Rate of turn too slow

(3) Failure to initiate corrective action based on the 30 second check

(4) Aircraft out of trim

(5) Failure to increase power before reaching desired altitude

9. Straight and Level

a. Performance Requirements

(1) Maintain heading (90^{o})

(2) Maintain altitude (1500 ft)

(3) Maintain airspeed (90 K)

b. Common Errors

(1) Failure to establish normal cruise airspeed (incorrect power setting)

(2) Heading errors

(3) Altitude errors

10. Level Left Turn

a. Performance Requirements

(1) Initial bank angle of 15^{o}. Adjust for standard rate turn by reference to turn needle

(2) Maintain airspeed (90 K)

(3) Maintain trim

(4) Maintain altitude (1500 ft)

(5) Check heading at 20 seconds

(6) Roll out on desired heading (330^{o})

b. Common Errors

(1) Non-standard rate turn

(2) Failure to roll out on desired heading

D. Initial Conditions

1. A/C location vicinity of CAIRNS Army Air Field

2. Heading 330^{o}

3. Airspeed 90 K

4. Altitude 2000 ft

5. Winds 110^{o}/10 K

E. Start-Stop Logic and Measures

Table 1 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanations of the measures start-stop logic codes. The word "ALL" in the first column means that the measure is applicable across each measurement segment of the maneuver segment.

F. Fatal Errors

Fatal errors which will cause termination of performance measurement are shown in Table 2.

Table 1

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE CLIMBING AND DESCENDING TURNS MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 1, Straight and Level	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	1	Start		Altitude (ALT)	5	2000 Ft
	1		TIM-20	Heading Tracking (HDT)	10	330^o
	2	CPS	CMB			
Segment 2, Climbing Left Turn	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	3	CPS	TIM-10			
	4	CPS		Rate of Climb (RC)	8	500 FPM
	4		SL	Average Turn Rate (ATR)	4	3^o/Sec
	5	CPS		Heading on Rollout (HOR)	9	240^o
	5			Heading Tracking (HDT)	10	240^o
	5		ALTA-2400	Rate of Climb (RC)	8	500 FPM
	6	CPS	TIM-15	Heading Tracking (HDT)	10	240^o
Segment 3, Straight and Level	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	7	CPS		Altitude (ALT)	5	2500 Ft
	7		TIM-20	Heading Tracking (HDT)	10	240^o
	8	CPS	DES			
Segment 4, Descending Right Turn	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	9	CPS	TIM-10			
	10	CPS		Rate of Descent (RD)	7	500 FPM
	10		SL	Average Turn Rate (ATR)	4	3^o/Sec
	11	CPS		Heading on Rollout (HOR)	9	330^o
	11			Heading Tracking (HDT)	10	330^o
	11		ALTB-1600	Rate of Descent (RD)	7	500 FPM
	12	CPS	TIM-15	Heading Tracking (HDT)	10	330^o
Segment 5, Straight and Level	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	13	CPS		Altitude (ALT)	5	1500 Ft
	13		TIM-20	Heading Tracking (HDT)	10	330^o
	14	CPS	CMB			

-continued-

-continued-

Table 1

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 6, Climbing Left Turn	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	15	CPS	TIM-10			
	16	CPS		Rate of Climb (RC)	8	500 FPM
	16		SL	Average Turn Rate (ATR)	4	3^{o}/Sec
	17	CPS		Heading on Rollout (HOR)	9	270^{o}
	17			Heading Tracking (HDT)	10	270^{o}
	17		ALTA-1900	Rate of Climb (RC)	8	500 FPM
	18	CPS	TIM-15	Heading Tracking (HDT)	10	270^{o}
Segment 7, Straight and Level	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	19	CPS		Altitude (ALT)	5	2000 Ft
	19		TIM-20	Heading Tracking (HDT)	10	270^{o}
	20	CPS	DES			
Segment 8, Descending Right Turn	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	21	CPS	TIM-10			
	22	CPS		Rate of Descent (RD)	7	500 FPM
	22		ALTB-1600	Average Turn Rate (ATR)	4	3^{o}/Sec
	23	CPS	SL			
	24	CPS		Heading on Rollout (HOR)	9	90^{o}
	24		TIM-15	Heading Tracking (HDT)	10	90^{o}
Segment 9, Straight and Level	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	25	CPS		Altitude (ALT)	5	1500 Ft
	25		TIM-20	Heading Tracking (HDT)	10	90^{o}
	26	CPS	LTR			
Segment 10, Level Left Turn	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	1500 Ft
	27	CPS	SL	Average Turn Rate (ATR)	4	3^{o}/Sec
	28	CPS		Heading on Rollout (HOR)	9	330^{o}
	28		TIM-30	Heading Tracking (HDT)	10	330^{o}

Table 2

FATAL ERRORS

CLIMBING AND DESCENDING TURNS

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF:		TIME MAX. (Sec)	AIRSPACE LIMITS	DIRECTION OF TURN	RADIO FREQUENCY	
				ABOVE	BELOW			WRONG	TYPE	FREQ.
$\geq$ 120 Knots	$\geq 30^{o}$	$\geq$ 1000 Ft	1	2250	1750	60	None		None	None
or		per min.	2	2750	1750	120		Right		
$\leq$ 60 Knots			3	2750	2250	60				
			4	2750	1250	120		Left		
			5	1750	1250	60				
			6	2250	1250	120		Right		
			7	2250	1750	60				
			8	2250	1250	120		Left		
			9	1750	1250	60				
			10	1750	1250	120		Right		

NDB APPROACH

A. General Description

The NDB approach problem requires the aviator to execute the NDB Runway 5 approach to Columbus Metropolitan Airport.

The problem requires the student to fly to the station, turn outbound and descend to procedure turn altitude, intercept and track the outbound course, procedure turn, track inbound to the station, descend to minimum descent altitude (MDA), time for the missed approach, and initiate the missed approach procedure.

B. Discussion

The performance requirements for the NDB approach are standard with two exceptions. First, after the pilot has crossed the beacon, he must turn and parallel the outbound course for one minute before turning to intercept the outbound course. If a pilot immediately turns and intercepts the outbound course after passing over the beacon, the start-stop logic may lose track of the aircraft and consequently abort the measurement run or the pilot may receive an erroneously poor score. Second, once the outbound course has been intercepted, the pilot is required to track outbound for two minutes. Both of these requirements are consistent with the procedures taught in IERW. Since it is expected that most pilots making automated performance assessment runs will be students, these requirements are compatible with the instruction they have received.

In all other respects, the performance requirements for the NDB approach are standard.

C. Maneuver Segmentation (See Figure 2)

1. Initial Tracking to the Station

   a. Performance Requirements

      (1) Track a course to the station (360°)

      (2) Maintain altitude (3000 ft)

      (3) Maintain normal cruise airspeed of 90 K

   b. Common Errors

      (1) S-turns resulting from the student "chasing" the ADF needle (homing) instead of holding a constant heading to track a course

      (2) Altitude errors resulting from poor instrument cross check (fixation on the RMI)

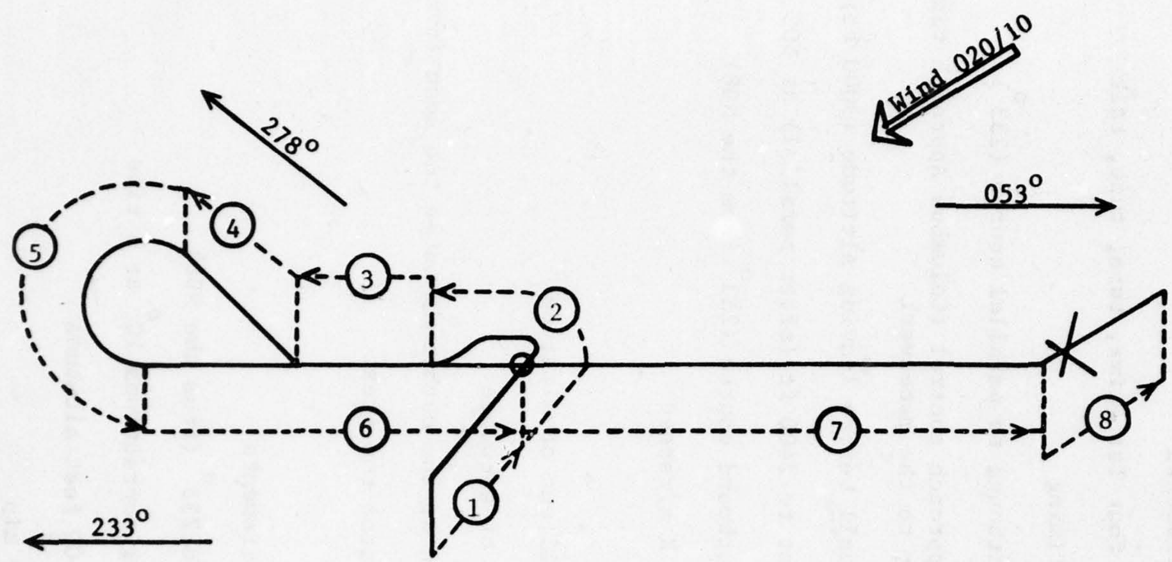


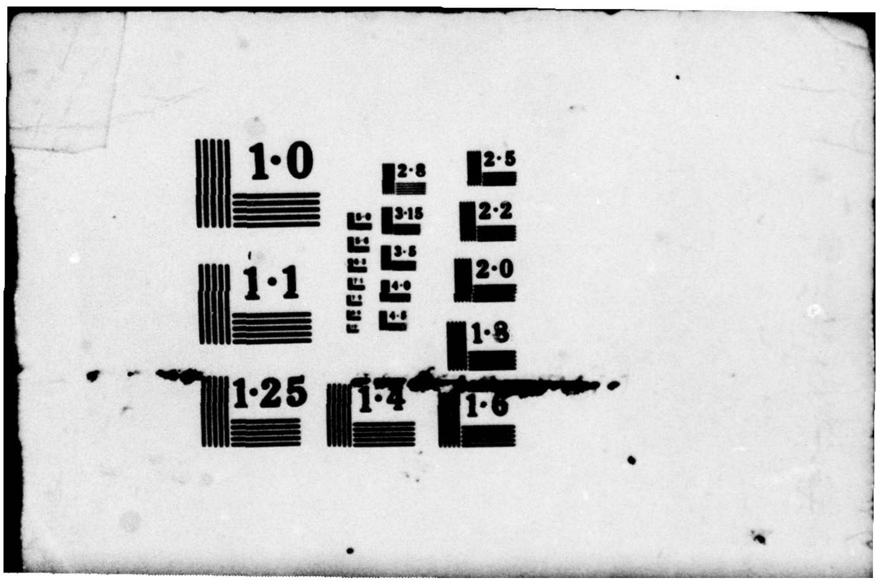
Figure 2

Schematic Representation of NDB Approach to Columbus Metropolitan Airport (Maneuver Segmentation Shown by Dashed Line. See Text for Segment Names.)

AD-A072 318 CANYON RESEARCH GROUP INC WESTLAKE VILLAGE CALIF F/G 5/9
DESIGN REQUIREMENTS FOR AN AUTOMATED PERFORMANCE MEASUREMENT AN--ETC(U)
JUN 79 R T HENNESSY, S F BARNEBEY DAHC19-77-C-0008
UNCLASSIFIED FTR-02-78 ARI-RR-1220 NL

2 OF 2
AD
A072318

END
DATE
FILMED
9 79
DDC


1·0
2·8
2·5
3·15
2·2
3·5
2·0
4·0
4·5
1·1
1·8
1·25
1·4
1·6

2. Beacon Outbound

a. Performance Requirements

(1) Execute the four Ts: time, turn, tune, talk

(a) Start timing

(b) Turn outbound to parallel course (233°)

(c) Tune approach control (Columbus Approach tuned prior to the maneuver)

(d) Radio call before leaving altitude (3000 ft)

(2) Begin descent to 2400 ft (after parallel) at 500 fpm

(3) Intercept outbound course (233° from the NDB)

(4) Maintain 90 K airspeed

b. Common Errors

(1) No radio call out of altitude

(2) Four Ts out of sequence

(3) Interception at the outbound course too soon (overshoot)

(4) Rate of descent too great

3. Tracking Outbound

a. Performance Requirements

(1) Track out on 233° (from the NDB)

(2) Make heading corrections 10° at a time

(3) Maintain 2400 feet altitude

(4) Track for 2 min

(5) Maintain 90 K airspeed

b. Common Errors

(1) Not considering the effect of winds

(2) Altitude errors

(3) Incorrect tracking procedure

(a) Make heading corrections 10^{o} at a time

(b) Wait for a 5^{o} deviation before correcting

4. Procedure Turn Outbound

a. Performance Requirements

(1) Turn to a heading of 278^{o}

(2) Time for 40 sec (adjust for wind effects). With a wind of 020/10, the time should be 43 sec

(3) Maintain 2400 ft altitude

(4) Maintain 90 K airspeed

b. Common Errors

(1) Not adjusting time for winds

(2) Trying to establish a track and not holding heading (278^{o})

5. Procedure Turn Inbound

a. Performance Requirements

(1) Standard rate turn

(2) Roll out on course (053^{o} NDB)

(3) Maintain 2400 ft altitude

(4) Maintain 90 K airspeed

b. Common Errors

(1) Non-standard rate of turn

(2) Altitude loss

(3) Failure to roll out on course

6. Tracking Inbound

a. Performance Requirements

(1) Track a course to the station

(2) Maintain 2400 ft altitude

(3) Tune radios for missed approach procedure (Columbus VOR 117.1)

b. Common Errors

(1) S-turns (resulting from "homing" rather than properly tracking to the station)

(2) Altitude loss - going below minimum altitude

(3) Radios not tuned for missed approach procedure

7. Beacon Inbound

a. Performance Requirements

(1) Execute the four Ts: time, turn, tune, talk

(a) Start timing for the MPA

(b) No turn required

(c) No radio call required because of radar surveillance

(2) Descend at 500 fpm to MDA at 960 ft

(3) Track a course when ADF becomes usable

(4) Maintain 960 feet altitude once attained

(5) Normal cruise airspeed at 90 K $\pm$ 10K

(6) Establish climb (power) after 4 min

b. Common Errors

(1) S-turns (resulting from "chasing" the ADF needle)

(2) Rate of descent too great

(3) Going below the MDA

(4) Improper timing for the MAP

(5) Slow to establish climb (with power) upon reaching the MAP

8. Missed Approach

a. Performance Requirements

(1) Apply sufficient power to establish climb

(2) Note the time

(3) Turn left to intercept the 045° bearing from FENIX NDB

(4) Radio call to Columbus Approach control (missed approach)

(5) Climb to 2500 direct to GEMMY Intersection and hold

b. Common Errors

(1) Insufficient power application

(2) Loss of airspeed

(3) Failure to comply with published missed approach procedures

D. Initial Conditions

1. A/C bearing 180° from FENIX NDB

2. 2 nautical miles from the NDB

3. Heading 360°

4. Airspeed 90 knots

5. Altitude 3000 feet

6. ADF receiver tuned to FENIX NDB frequency, 355

7. Marker beacon receiver ON

8. UHF receiver tuned to Columbus Approach frequency, 388.0

9. Winds 020°/10 knots

E. Start-Stop Logic and Measures

Table 3 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanation of the start-stop logic codes and the measures. The word "ALL" in the first column of the table means that the measure is applicable across each measurement segment of the maneuver segment.

Table 3

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE NDB APPROACH MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
NDB Approach	All			Airspeed (AS)	1	90 Knots
Segment 1, Initial Tracking to Beacon	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	3000 Ft
	1	Start	ACF-1	NDB Tracking (NBT)	12	360^{o}
	2	CPS	CCL-053^{o}	NDB Course Deviation (NCD)	13	0 Naut. Mi.
	3	CPS	LTR			
Segment 2, Turn and Intercept Outbound Course	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle	3	0^{o}
	All			Minimum Altitude (MAT)	6	2400 Ft
	4	CPS	SL	Average Turn Rate (ATR)	4	3^{o}/Sec
	5	CPS	DES	Radio Call Transmitted (RCT)	22	Mike Switch Closed
	6	CPS	TIM-10			
	7	CPS	TIM-50	Rate of Descent (RD)	7	500 FPM
	8	CPS	ACD-1			
	9	CPS	HDA-238^{o}			
Segment 3, Tracking Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	2400 Ft
	10	CPS		NDB Tracking (NBT)	12	233^{o}
	10		RTR	Time (TME)	11	120 Sec
	11	CPS	SL			
Segment 4, Procedure Turn Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	12	CPS		Minimum Altitude (MAT)	6	2400 Ft
	12			Heading on Rollout	9	278^{o}
	12			Heading Tracking (HDT)	10	IH
	12		LTR	Time (TME)	11	40 Sec
Segment 5, Procedure Turn Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	2400 Ft
	13	CPS	SL	Average Turn Rate	4	3^{o}/Sec
	14	CPS	HDA-53^{o}	NDB Course Position (NDP)	14	053^{o}

-continued-

-continued-

Table 3

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 6, Tracking Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	2400 Ft
	15	CPS	ACF-1	NDB Tracking (NBT)	12	053^{o}
	15	CPS	CCL-154^{o}	NDB Course Deviation (NCD)	13	0 Naut. Mi.
Segment 7, Beacon Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	960 Ft
	All			Time	11	204 Sec
	17	CPS	DES	Radio Call Transmitted (RCT)	22	Mike Switch Closed
	18	CPS	TIM-10			
	19	CPS		Rate of Descent (RD)	7	500 FPM
	19		ACF-1	NDB Course Deviation (NCD)	13	0 Naut. Mi.
	20	CPS		Rate of Descent (RD)	7	500 FPM
	20			NDB Tracking (NBT)	12	053^{o}
	20			VOR Tuning (VTN)	20	117.1
	20		ALTB-1000	OMNI Bearing Setting (OBS)	21	086^{o}
	21	CPS	TPC	NDB Tracking (NBT)	12	053^{o}
Segment 8, Missed Approach	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Radio Call Transmitted (RCT)	22	Mike Switch Closed
	22	CPS	CMB			
	23	CPS	TIM-10			
	24	CPS	TIM-150	Rate of Climb (RC)	8	500 FPM
	25	CPS	TIM-40	Heading on Rollout (HOR)	9	45^{o}

F. Fatal Errors

Fatal errors which will cause termination of performance measurements are shown in Table 4.

VOR APPROACH

A. General Description

The VOR approach requires the aviator to execute the VOR-A approach to Dothan Airport.

The aviator must fly to the VOR, report his arrival, turn, and fly outbound descending to the procedure turn altitude, make procedure turns to the inbound course, descend to intermediate approach segment altitude, track to the station and descend on course to minimum descent altitude, time for the missed approach point and after it is reached, initiate the missed approach procedure.

B. Discussion

The performance requirements for the VOR approach are standard with two exceptions. First, after the pilot has crossed the VOR, he must turn and parallel the outbound course for one minute before turning to intercept the outbound course. If a pilot immediately turns and intercepts the outbound course after passing over the VOR, the start-stop logic may lose track of the aircraft and consequently abort the measurement run or the pilot may receive an erroneously poor score. Second, once the outbound course has been intercepted, the pilot is required to track outbound for two minutes. Both of these requirements are consistent with the procedures taught in IERW. Since it is expected that most pilots making automated performance assessment runs will be students, these requirements are compatible with the instruction they have received.

In all other respects, the performance requirements for the VOR approach are standard.

C. Maneuver Segmentation (See Figure 3)

1. Initial Tracking to the VOR

a. Performance Requirements

(1) Track course to VOR (OBS set to 085°)

(2) Maintain altitude at 3000 ft

(3) 90 knots airspeed (all segments)

b. Common Errors

(1) S-turns from chasing Course Deviation Indicator (CDI) needle

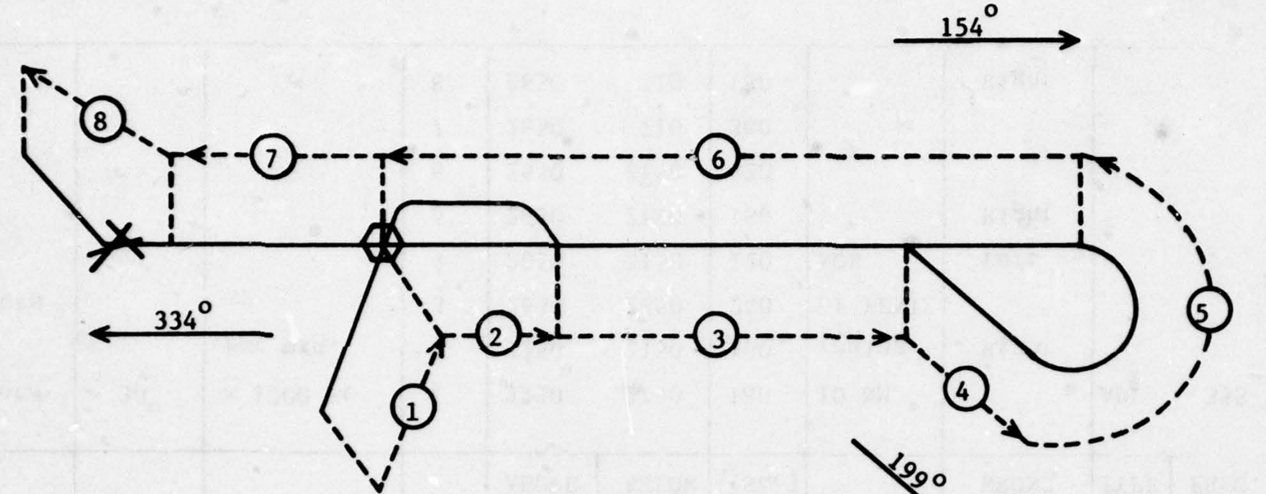
(2) Altitude errors from poor instrument cross check

Table 4

FATAL ERRORS

NDB APPROACH

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF:		TIME	AIRSPACE LIMITS	DIRECTION OF TURN	RADIO FREQUENCY	
				ABOVE	BELOW	MAX. (Sec)		WRONG	TYPE	FREQ.
$\geq$ 120 Knots	$\geq 30^{o}$	$\geq$ 1000 Ft	1	3250	2750	180	10 NM		ADF	355
or		per min.	2	3250	2150	180	radius	Right		
$\leq$ 60 Knots			3	2650	2150	240	of FENIX			
			4	2650	2150	120	NDB	Left		
			5	2650	2150	180		Right		
			6	2650	2150	420				
			7	2650	710	360				
			8	2650	710	180		Right		



WINDS: Calm

Figure 3

Schematic Representation of VOR-A Approach to Dothan Airport (Maneuver Segmentation Shown by Dashed Line. See Text for Segment Names.)

2. Turn and Intercept VOR Outbound Course

a. Performance Requirements

(1) Execute the 4 Ts: time, turn, tune, talk

(a) Start timing

(b) Turn outbound parallel to course (154°)

(c) Tune OBS to 334 (VOR frequency tuned prior to maneuver)

(d) Report intent to descend before leaving feeder altitude (3000 ft)

(2) Begin descent to 2000 ft (after parallel) at 500 fpm

(3) Intercept outbound course (154°) after one minute on parallel course

b. Common Errors

(1) Failure to report intent to change altitude

(2) Four Ts out of sequence

(3) Rate of descent too great

. Tracking Outbound

a. Performance Requirements

(1) Track out on outbound radial (154°)

(2) Track for at least 2 minutes

(3) Maintain 2000 ft altitude

(4) Make wind drift corrections 10° at a time

b. Common Errors

(1) Altitude errors

(2) Incorrect wind correction procedures

(a) Not incrementing wind corrections in 10° steps

(b) Making corrections before 2° error shown on CDI

4. Procedure Turn Outbound

a. Performance Requirements

(1) Turn to heading of 199^{o}

(2) Time for 40 seconds adjusted for winds

(3) Maintain 2000 ft altitude

(4) Reset OBS to 334^{o}

b. Common Errors

(1) Not adjusting time for winds

(2) Not maintaining 199^{o} heading (erroneously correcting heading for wind)

5. Procedure Turn Inbound

a. Performance Requirements

(1) Standard rate turn

(2) Roll out on course (334^{o})

(3) Maintain 2000 ft altitude until inbound course is established

(4) Tune UHF to tower frequency (257.7)

(5) Report inbound turn

b. Common Errors

(1) Non-standard turn rate

(2) Beginning descent before track is established

(3) Failure to roll out on course

(4) Altitude loss during turn

6. Tracking Inbound

a. Performance Requirements

(1) Track course to VOR

(2) Descend to 1200 ft at 500 fpm

(3) Maintain 1200 ft altitude when reached

b. Common Errors

(1) Improper tracking procedure

(a) Making heading change before CDI indicates 2^{o} error

(b) Not making wind corrections in 10^{o} increments

(2) Going below intermediate approach segment altitude

7. VOR Inbound (Final Approach)

a. Performance Requirements

(1) Execute the 4 Ts

(a) Start timing for the Missed Approach Point (MAP) (1:16)

(b) No turn required

(c) Tower frequency already tuned

(d) Report VOR inbound

(2) Descend to Minimum Descent Altitude (MDA) 860 ft at 500 fpm

(3) Maintain MDA when reached to Missed Approach Point

b. Common Errors

(1) Rate of descent too great

(2) Improper tracking procedure

(3) Going below minimum altitude

8. Missed Approach

a. Performance Requirements

(1) Initiate climb

(2) Report missed approach

(3) Establish 500 fpm climb rate

(4) Set OBS to 019^{o}

(5) Track straight ahead (334^{o}) to 1000 ft

(6) At 1000 ft continue climb to 2000 ft while turning right to 019^{o} radial

(7) Perform 4 Ts

(a) Note time at MAP

(b) Tune CAIRNS approach

(c) No immediate turn necessary

(d) Report missed approach - request other landing clearance

b. Common Errors

(1) Failure to apply sufficient power

(2) Loss of airspeed due to pitch

(3) Failure to comply with published procedures

(4) Perform 4 Ts out of sequence

D. Initial Conditions

1. A/C on 265^{o} radial of Dothan VOR

2. A/C 2 nautical miles from VOR

3. Heading 85^{o}

4. Altitude 3000 feet

5. Airspeed 90 knots

6. VOR receiver tuned to Dothan VOR (111.6)

7. UHF receiver tuned to CAIRNS approach control (234.4)

8. OBS set to 85^{o}

9. Winds calm

E. Start-Stop Logic and Measures

Table 5 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanation of the measures start-stop logic codes. The word "ALL" in the first column of the table means that the measure is applicable across each measurement segment of the maneuver segment.

F. Fatal Errors

Fatal errors which will cause termination of performance measurement are shown in Table 6.

Table 5

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE VOR APPROACH MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 1, Initial Tracking to VOR	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	3000 Ft
	1	Start		OMNI Bearing Setting (OBS)	21	085^{o}
	1		ACF-1	VOR Tracking (VTR)	15	265^{o}
	2	CPS	CCL-154^{o}	VOR Course Deviation (VCD)	16	0 Naut. Mi.
	3	CPS	RTR			
Segment 2, Turn and Intercept Outbound Course	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	2000 Ft
	4	CPS	SL	Average Turn Rate (ATR)	4	3^{o}/Sec
	5	CPS	DES	Radio Call Transmitted (RCT)	22	Mike Switch Closed
	6	CPS	TIM-10	OMNI Bearing Setting (OBS)	21	334^{o}
	7	CPS	TIM-50	Rate of Descent	7	500 FPM
	8	CPS	ACD-1			
	9	CPS	HDA-154^{o}			
Segment 3, Tracking Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	2000 Ft
	10	CPS		VOR Tracking (VRT)	15	154^{o}
	10		RTR	Time (TME)	11	120 Sec
	11	CPS	SL			
Segment 4, Procedure Turn Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	12	CPS		Altitude (ALT)	5	2000 Ft
	12			Heading on Rollout (HOR)	9	199^{o}
	12			Heading Tracking (HDT)	10	IH
	12		LTR	Time (TME)	11	40 Sec

-continued-

-continued-

Table 5

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 5, Procedure Turn Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	13	CPS		Minimum Altitude (MAT)	6	2000 Ft
	13		SL	Average Turn Rate (ATR)	4	3^{o}/Sec
	14	CPS		VOR Course Position (VCP)	17	334^{o}
	14		HDA-334^{o}	Altitude (ALT)	5	2000 Ft
	15	CPS	DES			
Segment 6, Tracking Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	1200 Ft
	16	CPS	TIM-10			
	17	CPS		Rate of Descent (RD)	7	500 FPM
	17		ALT-1400	VOR Tracking (VRT)	15	334^{o}
	18	CPS	ACF-1	VOR Tracking (VRT)	15	334^{o}
	18	CPS	CCL-64^{o}	VOR Course Deviation (VCD)	16	0 Naut. Mi.
Segment 7, VOR Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	860 Ft
	19	CPS	DES	Radio Call Transmitted (RCT)	22	Mike Switch Closed
	20	CPS	TIM-10	VOR Course Deviation (VCD)	16	0 Naut. Mi.
	21	CPS		VOR Course Deviation (VCD)	16	0 Naut. Mi.
	21		ALTB-900	Rate of Descent (RD)	7	500 FPM
	22	CPS	TPC	VOR Tracking (VRT)	15	334^{o}
Segment 8, Missed Approach	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Radio Call Transmitted (RCT)	22	Mike Switch Closed
	23	CPS	CMB			
	24	CPS	TIM-10			
	25	CPS	ALTA-1500	Rate of Climb	8	500 FPM
	26	CPS	TIM-110	OMNI Bearing Setting (OBS)	21	019^{o}

Table 6

FATAL ERRORS

VOR APPROACH

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF: ABOVE	ALTITUDE ERROR IF: BELOW	TIME MAX. (Sec)	AIRSPACE LIMITS	DIRECTION OF TURN WRONG	RADIO FREQUENCY TYPE	RADIO FREQUENCY FREQ.
$\geq$ 120 Knots	$\geq 30^{o}$	$\geq$ 1000 Ft	1	3250	2750	180	10 NM of		UHF	234.4
or		per min.	2	3250	1750	180	DOTHAN	Left	VOR	111.6
$\leq$ 60 Knots			3	3250	1750	180	VORTRAC			
			4	2250	1750	100		Left		
			5	2250	1750	180		Right		
			6	2250	950	420				
			7	2250	610	180				
			8	2250	610	180		Left		

ILS APPROACH

A. General Description

The ILS approach problem requires the aviator to execute the ILS Runway 9 approach to Dannelly Field, Montgomery, Alabama.

The problem requires the student to fly to the station, turn outbound, intercept and track the localizer course outbound, procedure turn, track the localizer course inbound, intercept and descend on the glideslope/localizer, and initiate the missed approach procedure upon reading the decision height (DH).

B. Discussion

The performance requirements for the ILS approach are standard with two exceptions. First, after the pilot has crossed the outer marker, he must turn and parallel the outbound course for one minute before turning to intercept the outbound course. If a pilot immediately turns and intercepts the outbound course after passing over the ILS, the start-stop logic may lose track of the aircraft and consequently abort the measurement run or the pilot may receive an erroneously poor score. Second, once the outbound course has been intercepted, the pilot is required to track outbound for two minutes. Both of these requirements are consistent with the procedures taught in IERW. Since it is expected that most pilots making automated performance assessment runs will be students, these requirements are compatible with the instruction they have received.

In all other respects, the performance requirements for the ILS approach are standard.

C. Maneuver Segmentation (See Figure 4)

1. Initial Tracking to the Station

   a. Performance Requirements

      (1) Track a course to the beacon (MARRA LOM 245)

      (2) Maintain altitude (2000 ft)

      (3) Maintain airspeed (90 K)

   b. Common Errors

      (1) S-turns (resulting from "chasing" the ADF needle)

      (2) Altitude errors resulting from poor instrument cross check (fixation on the ADF)

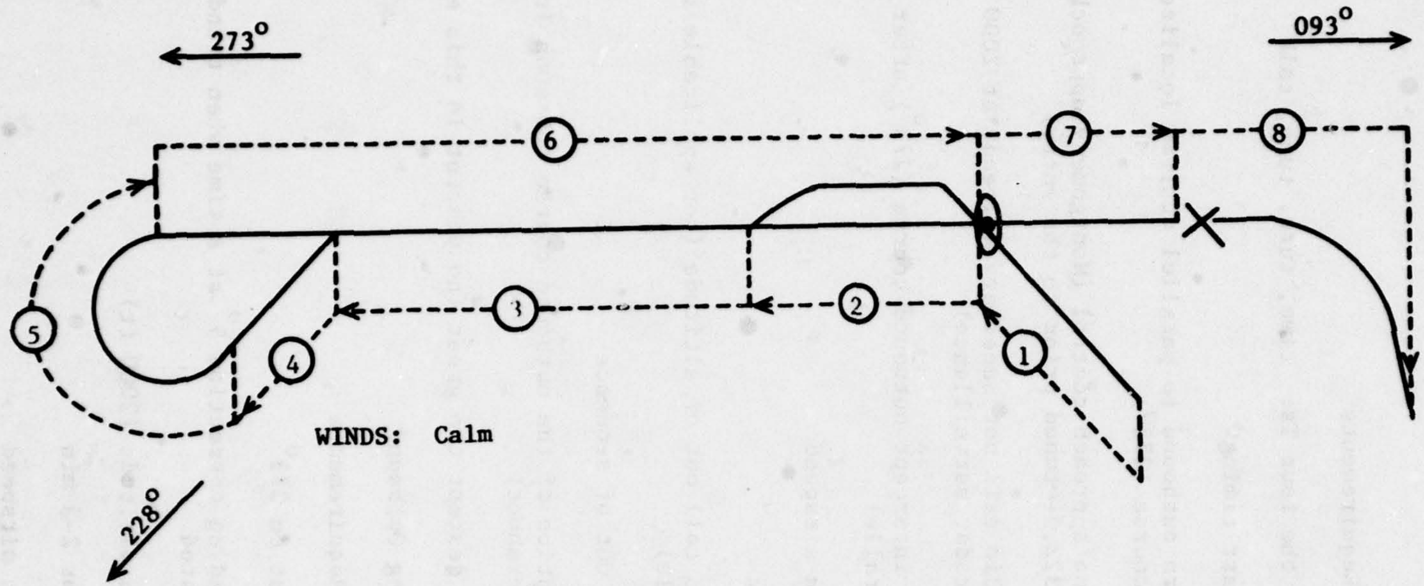


Figure 4

Schematic Representation of ILS Approach to Runway 9 at Dannelly Field (Maneuver Segments are Shown by Dashed Line. See Text for Segment Names.)

2. Beacon Outbound

a. Performance Requirements

(1) Execute the four Ts: time, turn, tune, talk

(a) Start timing

(b) Turn outbound to parallel desired localizer course (273^{o})

(c) Tune approach control (Montgomery approach control 322.5--tuned prior to the entry)

(d) Radio call not necessary (already at 2000 ft, radar surveillance)

(2) Turn to intercept outbound course (273^{o}) after 1 min at parallel

(3) 90 knots airspeed

b. Common errors

(1) No radio call out of altitude (not applicable in this example)

(2) Four Ts out of sequence

(3) Interception of the outbound course too soon (resulting in overshoot)

(4) Rate of descent too great (no descent in this example)

3. Localizer Tracking Outbound

a. Performance Requirements

(1) Track out on 273^{o}

(2) Make heading correction 5^{o} at a time when trend is indicated

(3) Maintain altitude (2000 ft)

(4) Track for 2-3 min

(5) 90 knots airspeed

b. Common Errors

(1) Altitude errors

(2) Incorrect tracking procedures

(a) Make heading changes 5^{o} at a time

(b) Wait for CDI to show a trend before initiating a correction

4. Procedure Turn Outbound

a. Performance Requirements

(1) Turn to heading of 228^{o}

(2) Time for 40 sec (adjust time for winds). Time for 40 sec with calm winds

(3) Maintain 2000 ft altitude

(4) 90 knots airspeed

b. Common Errors

(1) Not adjusting time for winds (or incorrect timing)

(2) Trying to establish a track

5. Procedure Turn Inbound

a. Performance Requirements

(1) Standard rate of turn

(2) Roll out on inbound localizer course

(3) Maintain 2000 ft altitude

(4) Normal cruise airspeed (90 K)

b. Common Errors

(1) Non-standard rate of turn

(2) Failure to roll out on course

(3) Altitude loss in the turn (below 2000 ft)

6. Localizer Tracking Inbound

a. Performance Requirements

(1) Track a course to the station. Making heading corrections 5° at a time when an off-course trend is shown (CDI on the edge of the doughnut)

(2) Maintain 2000 feet until glideslope interception

(3) 90 knots airspeed

b. Common Errors

(1) Improper tracking procedure

(2) Going below assigned altitude

7. Glideslope Interception Inbound

a. Performance Requirements

(1) Make immediate corrections to stay on glideslope/localizer

(2) Start timing upon NDB passage (for backup)

(3) Stay on the glideslope until the altimeter reads DH (418 ft), then pull power in for missed approach climb

(4) 90 knots airspeed

b. Common Errors

(1) Using middle marker for a MAP

(2) Going below the glideslope

8. Missed Approach

a. Performance Requirements

(1) Apply sufficient power to establish climb

(2) Note the time

(3) Climb straight ahead to 620, then climbing right turn to 2000 via 180° heading and MGM VORTAC R-226 to Aloon Int and hold

(4) MGM VORTAC tuned 112.1, OBS set to 226

(5) Radio call to Montgomery Approach Control (missed approach)

b. Common Errors

(1) Insufficient power application

(2) Loss of airspeed

(3) Failure to comply with published missed approach procedure ((3) above)

D. Initial Conditions

1. A/C 2 miles southeast of Montgomery Locator Outer Marker

2. Heading 318°

3. Airspeed 90 knots

4. Altitude 2000 feet

5. ADF tuned to MARRA, frequency 245

6. Marker beacon receiver ON

7. UHF to Montgomery Approach Control, frequency 322.5

8. VOR/ILS receiver tuned to ILS, frequency 109.9

9. Winds calm

E. Start-Stop Logic and Measures

Table 7 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanation of the measures start-stop logic codes. The word "ALL" in the first column of the table means that the measure is applicable across each measurement segment of the maneuver segment.

F. Fatal Errors

Fatal errors which will cause termination of performance measurement are shown in Table 8.

Table 7

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE ILS APPROACH MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 1, Initial Tracking to Beacon	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	All			Altitude (ALT)	5	2000 Ft
	1	Start	ACF-1	NDB Tracking (NBT)	12	318^o
	2	CPS	CCL-ILS 093^o	NDB Course Deviation (NCD)	13	0 Naut. Mi.
	3	CPS	RTR			
Segment 2, Inbound Intercept Outbound Course	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	All			Minimum Altitude (MAT)	6	6000 Ft
	4	CPS	SL	Average Turn Rate (ATR)	4	3^o/Sec
	5	CPS	ACB-.1			
	6	CPS	HDA-273^o			
Segment 3, Tracking Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	All			Minimum Altitude (MAT)	6	2000 Ft
	7	CPS		Localizer Tracking (LZT)	18	0^o
	7		LTR	Time (TME)	11	120 Sec
	8	CPS	SL			
Segment 4, Procedure Turn Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	9	CPS		Minimum Altitude (MAT)	6	2000 Ft
	9			Heading on Rollout (HOR)	9	228^o
	9			Heading Tracking (HDT)	10	IH
	9		RTR	Time (TME)	11	40 Sec
Segment 5, Procedure Turn Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	All			Minimum Altitude (MAT)	6	2000 Ft
	10	CPS	SL	Average Turn Rate (ATR)	5	3^o/Sec
	11	CPS	HDS-93^o			

-continued-

-continued-

Table 7

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 6, Tracking Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	12	CPS		Minimum Altitude (MAT)	6	2000 Ft
	12		CCL-LOM 003^{o}	Localizer Tracking (LZT)	18	0^{o}
Segment 7, Glideslope Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	418 Ft
	All			Time (TME)	11	204 Sec
	13	CPS	TIM-10	Localizer Tracking (LZT)	18	0^{o}
	14	CPS		Localizer Tracking (LZT)	18	0^{o}
	14		ALTB-600	Glideslope Tracking (GST)	19	0^{o}
	15	CPS	TPC			
Segment 8, Missed Approach	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	418 Ft
	16	CPS	CMB			
	17	CPS	TIM-10			
	18	CPS	ALTA-1000	Rate of Climb (RC)	8	500 FPM
	19	CPS		Rate of Climb (RC)	8	500 FPM
	19			Heading on Rollout	9	180^{o}
	19			VOR Tuning (VTN)	20	112.1
	19		ALTA-1600	OMNI Bearing Setting (OBS)	21	226^{o}

Table 8

FATAL ERRORS

ILS APPROACH

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF: ABOVE	ALTITUDE ERROR IF: BELOW	TIME MAX. (Sec)	AIRSPACE LIMITS	DIRECTION OF TURN WRONG	RADIO FREQUENCY TYPE	RADIO FREQUENCY FREQ.
$\geq$ 120 Knots or $\leq$ 60 Knots	$\geq 30^{o}$	$\geq$ 1000 Ft per min.	1	2250	1750	180	10 NM radius of MARRA LOM		ADF	245
			2	[illegible]50	1750	180		Right	ILS	109.9
			3	2250	1750	240				
			4	2250	1750	120		Right		
			5	2250	1750	180		Left		
			6	2250	1750	420				
			7	2250	168	360				
			8	2250.	168	180		Left		

LOCALIZER BACKCOURSE APPROACH

A. General Description

The localizer backcourse approach problem requires the aviator to execute the backcourse localizer approach to Runway 13 of Dothan Airport.

The aviator must fly to intercept the backcourse, turn and track the localizer course, receive a radar fix at Arcus Intersection, begin the descent to the Minimum Descent Altitude (MDS) and time for the Missed Approach Point (MAP), level off at the MDS, and initiate the missed approach procedure wher he MAP is reached.

B. Discussion

The performance requirements for the localizer backcourse approach are standard. There are not special performance requirements that are idiosyncratic to IERW training or the performance measurement system.

C. Maneuver Segmentation (See Figure 5)

1. Interception of the Localizer Course

a. Performance Requirements

(1) Maintain heading to localizer course (150^{o})

(2) Maintain altitude at 2000 ft

(3) 90 knots airspeed (all segments)

(4) Set OBS to missed approach course (019^{o})

(5) Turn to inbound heading (133^{o}) at interception

b. Common Errors

(1) Failure to intercept

(2) OBS not set for missed approach

2. Tracking Inbound to Fix

a. Performance Requirements

(1) Track localizer course

(2) Maintain altitude

(3) Make 5^{o} heading changes when off-course trend is shown - CDI on edge of doughnut

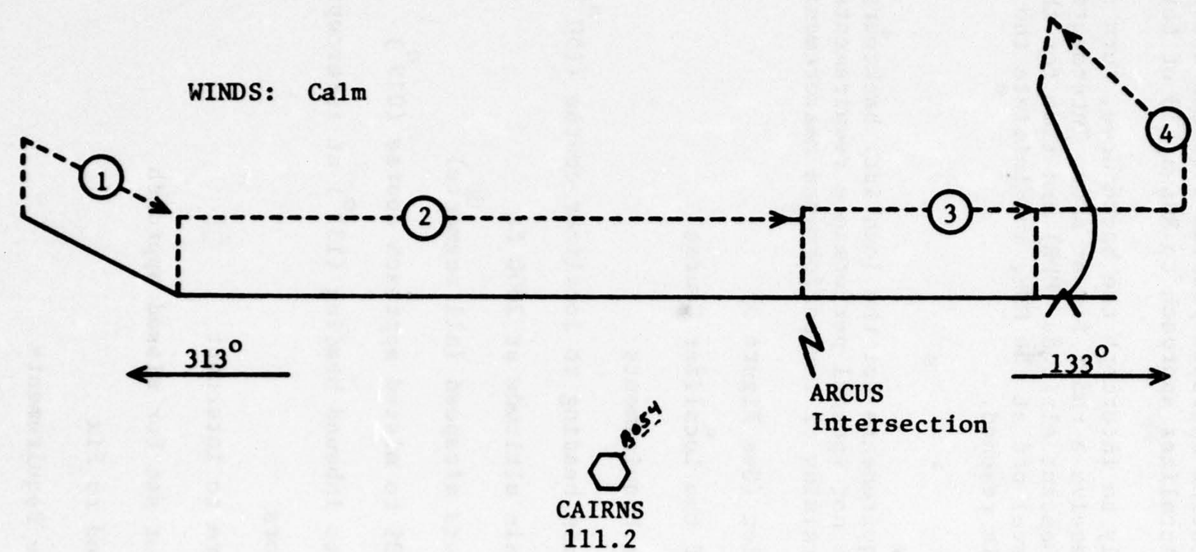


Figure 5

Schematic Representation of Localizer Backcourse Approach to Runway 13, Dothan Airport
(Maneuver Segments are Shown by Dashed Line. See Text for Segment Names.)

b. Common Errors

(1) Turning toward instead of away from CDI direction of deflection

(2) Altitude errors

3. Intersection Inbound

a. Performance Requirements

(1) Establish 500 fpm descent

(2) Start timing for the MAP (200 sec)

(3) Maintain course

(4) Maintain MDA (740 ft) when reached

b. Common Errors

(1) Turning toward instead of away from CDI direction of deflection

4. Missed Approach

a. Performance Requirements

(1) Initiate climb

(2) Report missed approach

(3) Establish 500 fpm climb

(4) Turn left to intercept 019^{o} instead of Dothan VORTAC

(5) Perform 4 Ts

(a) Note time at MAP (beginning of segment)

(b) Tune CAIRNS approach

(c) Turn already initiated

(d) Report missed approach - request further instructions

b. Common Errors

(1) Failure to apply sufficient power

(2) Loss of airspeed due to pitch

(3) Failure to comply with published procedures

(4) Perform 4 Ts out of sequence

D. Initial Conditions

1. A/C 10 NM northeast of Dothan Airport

2. Heading 150^{o}

3. Altitude 2000 feet

4. Airspeed 90 knots

5. VOR tuned to Dothan ILS (108.3)

6. UHF receiver tuned to CAIRNS Approach Control (254.4)

7. OBS set to 019^{o}

8. Winds calm

E. Start-Stop Logic and Measures

Table 9 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanation of the measures start-stop logic codes. The word "ALL" in the first column of the table means that the measure is applicable across each measurement segment of the maneuver segment.

F. Fatal Errors

Fatal errors which will cause termination of performance measurement are shown in Table 10.

HOLDING AT INTERSECTION

A. General Description

The holding at intersection advanced instrument problem requires the aviator to maintain a standard right turn holding pattern at the intersection of the 112^{o} radial of the Tuskegee VORTAC and the 053^{o} course to the FENIX nondirectional radio beacon (NDB). This fix is named the SEALI intersection. The inbound holding course is 053^{o}.

In general, the problem requires the student to fly to the fix, report his arrival at the fix, enter the holding pattern on the outbound leg, turn onto the inbound leg, cross the fix and subsequently make three complete holding circuits, after which the problem is terminated.

B. Discussion

The performance requirements for holding at intersection are standard. There are no performance requirements that are idiosyncratic to the procedures taught during IERW of the performance measurement system.

Table 9

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE LOCALIZER BACKCOURSE APPROACH MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 1, Intercept Localizer Course	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	2000 Ft
	1	Start		OMNI Bearing Setting (OBS)	21	019^{o}
	1		TIM-60	Heading Tracking (HDT)	10	150^{o}
	2	CPS	HDA-133^{o}			
Segment 2, Tracking Inbound to Fix	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	3	CPS		Minimum Altitude (MAT)	6	2000 Ft
	3		RRF	Localizer Tracking (LZT)	18	0^{o}
Segment 3, Fix Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Time (TME)	11	200 Sec
	All			Minimum Altitude (MAT)	6	740 Ft
	4	CPS		Radio Call Transmitted (RCT)	22	Mike Switch Closed
	4		DES	Localizer Tracking (LZT)	18	0^{o}
	5	CPS		Radio Call Transmitted (RCT)	22	Mike Switch Closed
	5		TIM-10	Localizer Tracking (LZT)	18	0^{o}
	6	CPS		Localizer Tracking (LZT)	18	0^{o}
	6		ALTB-1000	Rate of Descent (RD)	7	500 FPM
	7	CPS	TPC			
Segment 4, Missed Approach	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Minimum Altitude (MAT)	6	740 Ft
	All			Radio Call Transmitted (RCT)	22	Mike Switch Closed
	8	CPS	CMB			
	9	CPS	LTR			
	10	CPS		Rate of Climb (RC)	8	500 FPM
	10	HDA-19^{o}		Average Turn Rate (ATR)	4	3^{o}/Sec

Table 10

FATAL ERRORS

LOCALIZER BACKCOURSE APPROACH

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF: ABOVE	BELOW	TIME MAX. (Sec)	AIRSPACE LIMITS	DIRECTION OF TURN WRONG	RADIO FREQUENCY TYPE	FREQ.
≥ 120 Knots	≥ 30°	≥ 1000 Ft	1	2250	1750	120	10 NM		UHF	234.4
or		per min.	2	2250	1750	300	of ARCUS	Right	ILS	108.3
≤ 60 Knots			3	2250	490	240	Inter-section			
			4	2250	490	240		Left		

C. Maneuver Segmentation (see Figure 6)

1. Initial Track to Holding Fix

a. Performance Requirements

(1) Track course to intersection (set OBS to 112°)

(2) Maintain 4000 ft altitude (all segments)

(3) 90 knots airspeed (all segments)

(4) Cross fix

b. Common Errors

(1) Altitude errors due to poor instrument cross check

(2) Drift off course

2. Entry Right Turn to Outbound Course

a. Performance Requirements

(1) Make standard rate turn

(2) Roll out on heading parallel to holding course

b. Common Errors

(1) Non-standard rate turn

(2) Turn wrong direction

3. Entry Outbound Course

a. Performance Requirements

(1) Fly for 1 min

(2) Apply appropriate heading correction for known wind effects

b. Common Errors

(1) Outbound leg exceeds 1 min

4. Entry Right Turn to Inbound Course

a. Performance Requirements

(1) Make standard rate right turn

(2) Roll out on heading to intercept inbound course

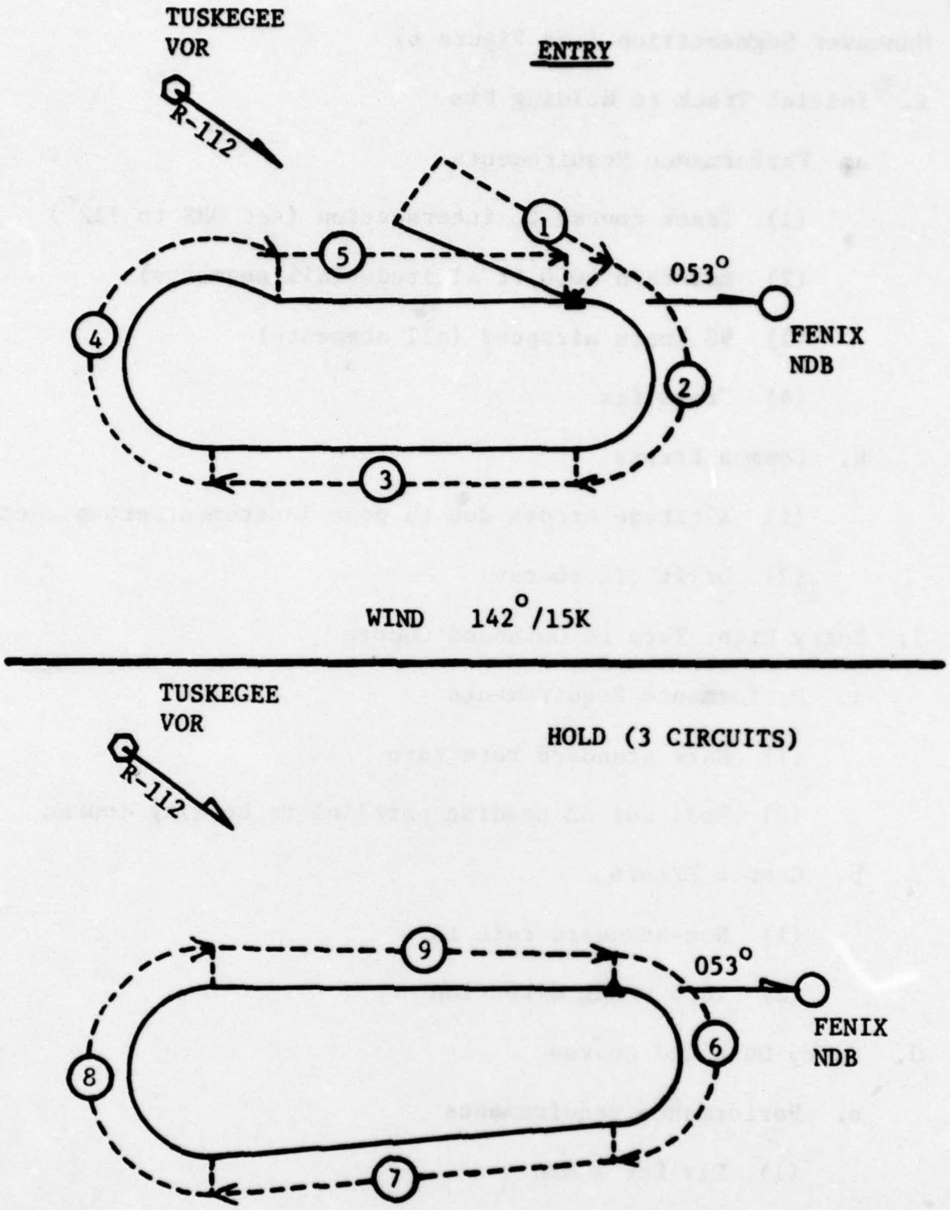


Figure 6

Schematic Representation of Holding at Intersection (SEALI) (Maneuver Segments are Shown by Dashed Line. See Text for Segment Names.)

b. Common Errors

(1) Non-standard rate turn

(2) Failure to roll out on heading to intercept inbound course

5. Entry Inbound Course

a. Performance Requirements

(1) Intercept and fly inbound course to fix

(2) Determine inbound time

(3) Apply heading correction for wind to maintain course

b. Common Errors

(1) Failure to make heading correction for wind to maintain course

6. Right Turn to Outbound Course

a. Performance Requirements

(1) Make standard rate right turn

(2) Roll out on wind corrected heading

b. Common Errors

(1) Non-standard rate turn

7. Outbound Course

a. Performance Requirements

(1) Maintain wind corrected heading

(2) Adjust outbound time to result in 1 min inbound time

b. Common Errors

(1) Outbound time not correct for 1 min inbound time

8. Right Turn to Inbound Course

a. Performance Requirements

(1) Make standard rate right turn

(2) Roll out on inbound course

b. Common Errors

(1) Non-standard rate turn

(2) Roll out not on inbound course

9. Inbound Course

a. Performance Requirements

(1) Fly inbound course to fix

(2) Apply wind correction to heading

(3) Time inbound leg

b. Common Errors

(1) Failure to make appropriate wind correction

NOTE: Performance requirements and common errors for segments 6-9 are the same respectively for segments 10-13 and 14-17 which are two additional circuits of the holding pattern.

D. Initial Conditions

1. A/C on 112° radial of Tuskegee VORTAC

2. 2 nautical miles from the SEALI intersection

3. Heading 112°

4. Airspeed 90 knots

5. Altitude 4000 feet (holding altitude)

6. ADF receiver tuned to FENIX 355

7. VOR receiver tuned to Tuskegee VORTAC (117.3)

8. OMNI Bearing Selector (OBS) set to 112°

9. Winds 142°/15 knots

E. Start-Stop Logic and Measures

Table 11 shows the specific start-stop logic and measures applicable during each segment of the maneuver. Refer to Tables II-1 and II-2 and associated text for detailed explanations of the measures start-stop logic codes. The word "ALL" in the first column of the table means that the measure is applicable across each measurement segment of the maneuver segment.

Table 11

START-STOP LOGIC AND MEASURES APPLICABLE TO EACH SEGMENT OF THE HOLDING AT INTERSECTION MANEUVER

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 1, Initial Tracking to Fix	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	4000 Ft
	1	Start		VOR Tracking (VRT)	15	112^{o}
	1		CCL-NDB 053^{o}	OMNI Bearing Setting (OBS)	21	112^{o}
	2	CPS	RTR			
Segment 2, Entry Right Turn Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	4000 Ft
	3	CPS	SL	Average Turn Rate (ATR)	4	3^{o}/Sec
Segment 3, Entry Track Outbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	4	CPS	RTR	Altitude (ALT)	5	4000 Ft
Segment 4, Entry Right Turn Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	5	CPS	SL	Altitude (ALT)	5	4000 Ft
	5			Average Turn Rate (ATR)	4	3^{o}/Sec
Segment 5, Entry Track Inbound	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	All			Altitude (ALT)	5	4000 Ft
	6	CPS	CCL-VOR 112^{o}	NDB Tracking (NBT)	12	053^{o}
	7	CPS	RTR			
Segment 6, Right Turn Outbound-1	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	8	CPS		Altitude (ALT)	5	4000 Ft
	8		SL	Average Turn Rate (ATR)	4	3^{o}/Sec
		N.B.	Holding pattern is repeated three times - Segments 6-16			
Segment 7, Track Outbound-1	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	9	CPS		Altitude (ALT)	5	4000 Ft
	9			Heading on Rollout (HOR)	9	213^{o}
	9		RTR	Heading Tracking (HDT)	10	From above

-continued-

-continued-

Table 11

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 8, Right Turn Inbound-1	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	10	CPS		Altitude (ALT)	5	4000 Ft
	10		SL	Average Turn Rate (ATR)	4	3^o/Sec
Segment 9, Track Inbound-1	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	11	CPS		Altitude (ALT)	4	4000 Ft
	11			Time (TME)	11	60 Sec
	11	CCL-VOR 112^o		NDB Tracking (NBT)	12	053^o
Segment 10, Right Turn Outbound-2	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	12	CPS		Altitude (ALT)	5	4000 Ft
	12		SL	Average Turn Rate (ATR)	4	3^o/Sec
Segment 11, Track Outbound-2	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	13	CPS		Altitude (ALT)	5	4000 Ft
	13			Heading on Rollout (HOR)	9	213^o
	13		RTR	Heading Tracking (HDT)	10	From above
Segment 12, Right Turn Inbound-2	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^o
	14	CPS		Altitude (ALT)	5	4000 Ft
	14		SL	Average Turn Rate (ATR)	4	3^o/Sec

-continued-

-continued-

Table 11

MANEUVER/SEGMENT	MEASUREMENT SEGMENT	START	STOP	MEASURE	MEASURE NO.	DESIRED VALUE
Segment 13, Track Inbound-2	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	14	CPS		Altitude (ALT)	5	4000 Ft
	14			Time (TME)	11	60 Sec
	14		CCL-VOR 112^{o}	NDB Tracking (NBT)	12	053^{o}
Segment 14, Right Turn Outbound-3	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	15	CPS		Altitude (ALT)	5	4000 Ft
	15		SL	Average Turn Rate (ATR)	4	3^{o}/Sec
Segment 15, Track Outbound-3	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	16	CPS		Altitude (ALT)	5	4000 Ft
	16			Heading on Rollout (HOR)	9	213^{o}
	16		RTR	Heading Tracking (HDT)	10	From above
Segment 16, Right Turn Inbound-3	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	17	CPS		Altitude (ALT)	5	4000 Ft
	17		SL	Average Turn Rate (ATR)	4	3^{o}/Sec
Segment 17, Track Inbound-3	All			Airspeed (AS)	1	90 Knots
	All			Trim (TR)	2	0 Ball Width
	All			Bank Angle (BA)	3	0^{o}
	18	CPS		Altitude (ALT)	5	4000 Ft
	18			Time (TME)	11	60 Sec
	18		CCL-VOR 112^{o}	NDB Tracking (NBT)	12	053^{o}

F. Fatal errors which will cause termination of performance measurement are shown in Table 12.

Table 12

FATAL ERRORS

HOLDING AT INTERSECTION

AIRSPEED	BANK ANGLE	RATE OF DESCENT	SEG.	ALTITUDE ERROR IF: ABOVE	ALTITUDE ERROR IF: BELOW	TIME MAX. (Sec)	AIRSPACE LIMITS	DIRECTION OF TURN WRONG	RADIO FREQUENCY TYPE	RADIO FREQUENCY FREQ.
$\geq$ 120 Knots	$\geq 30^{o}$	$\geq$ 1000 Ft	1	4250	3750	180	6 NM	Left	ADF	355
or		per min.	t	"	"	"	From Inter-	"	VOR	117.3
$\leq$ 60 Knots			h	"	"	"	section	"		
			r	"	"	"	(VOR 112^{o}	"		
			o	"	"	"	and ADF 056^{o})	"		
			u	"	"	"	Inter-	"		
			g	"	"	"	section TUSKEGEE	"		
			h	" .	"	"	VORTAC	"		
			17	4250	3750	180	FENIX NDB	Left		

DISTRIBUTION

ARI Distribution List

4 OASD (M&RA)
2 HQDA (DAMI-CSZ)
1 HQDA (DAPE PBR)
1 HQDA (DAMA AR)
1 HQDA (DAPE-HRE-PO)
1 HQDA (SGRD-ID)
1 HQDA (DAMI-DOT-C)
1 HQDA (DAPC-PMZ-A)
1 HQDA (DACH-PPZ-A)
1 HQDA (DAPE-HRE)
1 HQDA (DAPE-MPO-C)
1 HQDA (DAPE-DW)
1 HQDA (DAPE-HRL)
1 HQDA (DAPE-CPS)
1 HQDA (DAFD-MFA)
1 HQDA (DARD-ARS-P)
1 HQDA (DAPC-PAS-A)
1 HQDA (DUSA-OR)
1 HQDA (DAMO-RQR)
1 HQDA (DASG)
1 HQDA (DA10-PI)
1 Chief, Consult Div (DA-OTSG), Adelphi, MD
1 Mil Asst. Hum Res, ODDR&E, OAD (E&LS)
1 HQ USARAL, APO Seattle, ATTN: ARAGP-R
1 HQ First Army, ATTN: AFKA-OI TI
2 HQ Fifth Army, Ft Sam Houston
1 Dir, Army Stf Studies Ofc, ATTN: OAVCSA (DSP)
1 Ofc Chief of Stf, Studies Ofc
1 DCSPER, ATTN: CPS/OCP
1 The Army Lib, Pentagon, ATTN: RSB Chief
1 The Army Lib, Pentagon, ATTN: ANRAL
1 Ofc, Asst Sect of the Army (R&D)
1 Tech Support Ofc, OJCS
1 USASA, Arlington, ATTN: IARD-T
1 USA Rsch Ofc, Durham, ATTN: Life Sciences Dir
2 USARIEM, Natick, ATTN: SGRD-UE-CA
1 USATTC, Ft Clayton, ATTN: STETC-MO-A
1 USAIMA, Ft Bragg, ATTN: ATSU-CTD-OM
1 USAIMA, Ft Bragg, ATTN: Marquat Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Tng Dir
1 USA Quartermaster Sch, Ft Lee, ATTN: ATSM-TE
1 Intelligence Material Dev Ofc, EWL, Ft Holabird
1 USA SE Signal Sch, Ft Gordon, ATTN: ATSO-EA
1 USA Chaplain Ctr & Sch, Ft Hamilton, ATTN: ATSC-TE-RD
1 USATSCH, Ft Eustis, ATTN: Educ Advisor
1 USA War College, Carlisle Barracks, ATTN: Lib
2 WRAIR, Neuropsychiatry Div
1 DLI, SDA, Monterey
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-MR
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-JF
1 USA Arctic Test Ctr, APO Seattle, ATTN: STEAC-PL-MI
1 USA Arctic Test Ctr, APO Seattle, ATTN: AMSTE-PL-TS
1 USA Armament Cmd, Redstone Arsenal, ATTN: ATSK-TEM
1 USA Armament Cmd, Rock Island, ATTN: AMSAR-TDC
1 FAA-NAFEC, Atlantic City, ATTN: Library
1 FAA-NAFEC, Atlantic City, ATTN: Human Engr Br
1 FAA Aeronautical Ctr, Oklahoma City, ATTN: AAC-44D
2 USA Fld Arty Sch, Ft Sill, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DI-E
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DT-TP
1 USA Armor Sch, Ft Knox, ATTN: ATSB-CD-AD
2 HQUSACDEC, Ft Ord, ATTN: Library
1 HQUSACDEC, Ft Ord, ATTN: ATEC-EX-E-Hum Factors
2 USAEEC, Ft Benjamin Harrison, ATTN: Library
1 USAPACDC, Ft Benjamin Harrison, ATTN: ATCP-HR
1 USA Comm-Elect Sch, Ft Monmouth, ATTN: ATSN-EA
1 USAEC, Ft Monmouth, ATTN: AMSEL-CT-HDP
1 USAEC, Ft Monmouth, ATTN: AMSEL-PA-P
1 USAEC, Ft Monmouth, ATTN: AMSEL-SI-CB
1 USAEC, Ft Monmouth, ATTN: C, Facl Dev Br
1 USA Materials Sys Anal Agcy, Aberdeen, ATTN: AMXSY-P
1 Edgewood Arsenal, Aberdeen, ATTN: SAREA-BL-H
1 USA Ord Ctr & Sch, Aberdeen, ATTN: ATSL-TEM-C
2 USA Hum Engr Lab, Aberdeen, ATTN: Library/Dir
1 USA Combat Arms Tng Bd, Ft Benning, ATTN: Ad Supervisor
1 USA Infantry Hum Rsch Unit, Ft Benning, ATTN: Chief
1 USA Infantry Bd, Ft Benning, ATTN: STEBC-TE-T
1 USASMA, Ft Bliss, ATTN: ATSS-LRC
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA-CTD-ME
1 USA Air Def Sch, Ft Bliss, ATTN: Tech Lib
1 USA Air Def Bd, Ft Bliss, ATTN: FILES
1 USA Air Def Bd, Ft Bliss, ATTN: STEBD-PO
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Lib
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: ATSW-SE-L
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Ed Advisor
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: DepCdr
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: CCS
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCASA
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACO-E
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACC-CI
1 USAECOM, Night Vision Lab, Ft Belvoir, ATTN: AMSEL-NV-SD
3 USA Computer Sys Cmd, Ft Belvoir, ATTN: Tech Library
1 USAMERDC, Ft Belvoir, ATTN: STSFB-DQ
1 USA Eng Sch, Ft Belvoir, ATTN: Library
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-TD-S
1 USA Topographic Lab, Ft Belvoir, ATTN: STINFO Center
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-GSL
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATS-CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TE
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEX-GS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTS-OR
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-DT
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-CS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: DAS/SRD
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEM
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: Library
1 CDR, HQ Ft Huachuca, ATTN: Tech Ref Div
2 CDR, USA Electronic Prvg Grd, ATTN: STEEP-MT-S
1 HQ, TCATA, ATTN: Tech Library
1 HQ, TCATA, ATTN: AT CAT-OP-Q, Ft Hood
1 USA Recruiting Cmd, Ft Sheridan, ATTN: USARCPM-P
1 Senior Army Adv., USAFAGOD/TAC, Elgin AF Aux Fld No. 9
1 HQ, USARPAC, DCSPER, APO SF 96558, ATTN: GPPE-SE
1 Stimson Lib, Academy of Health Sciences, Ft Sam Houston
1 Marine Corps Inst., ATTN: Dean-MCI
1 HQ, USMC, Commandant, ATTN: Code MTMT
1 HQ, USMC, Commandant, ATTN: Code MPI-20-28
2 USCG Academy, New London, ATTN: Admission
2 USCG Academy, New London, ATTN: Library
1 USCG Training Ctr, NY, ATTN: CO
1 USCG Training Ctr, NY, ATTN: Educ Svc Ofc
1 USCG, Psychol Res Br, DC, ATTN: GP 1/62
1 HQ Mid-Range Br, MC Det, Quantico, ATTN: P&S Div

1 US Marine Corps Liaison Ofc, AMC, Alexandria, ATTN: AMCGS-F
1 USATRADOC, Ft Monroe, ATTN: ATRO-ED
6 USATRADOC, Ft Monroe, ATTN: ATPR-AD
1 USATRADOC, Ft Monroe, ATTN: ATTS-EA
1 USA Forces Cmd, Ft McPherson, ATTN: Library
2 USA Aviation Test Bd, Ft Rucker, ATTN: STEBG-PO
1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Library
1 USA Agcy for Aviation Safety, Ft Rucker, ATTN: Educ Advisor
1 USA Aviation Sch, Ft Rucker, ATTN: PO Drawer O
1 HQUSA Aviation Sys Cmd, St Louis, ATTN: AMSAV-ZDR
2 USA Aviation Sys Test Act., Edwards AFB, ATTN: SAVTE-T
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA TEM
1 USA Air Mobility Rsch & Dev Lab, Moffett Fld, ATTN: SAVDL-AS
1 USA Aviation Sch, Res Tng Mgt, Ft Rucker, ATTN: ATST-T-RTM
1 USA Aviation Sch, CO, Ft Rucker, ATTN: ATST-D-A
1 HQ, DARCOM, Alexandria, ATTN: AMXCD-TL
1 HQ, DARCOM, Alexandria, ATTN: CDR
1 US Military Academy, West Point, ATTN: Serials Unit
1 US Military Academy, West Point, ATTN: Ofc of Milt Ldrshp
1 US Military Academy, West Point, ATTN: MAOR
1 USA Standardization Gp, UK, FPO NY, ATTN: MASE-GC
1 Ofc of Naval Rsch, Arlington, ATTN: Code 452
3 Ofc of Naval Rsch, Arlington, ATTN: Code 458
1 Ofc of Naval Rsch, Arlington, ATTN: Code 450
1 Ofc of Naval Rsch, Arlington, ATTN: Code 441
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Acous Sch Div
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L51
1 Naval Aerospc Med Res Lab, Pensacola, ATTN: Code L5
1 Chief of NavPers, ATTN: Pers-OR
1 NAVAIRSTA, Norfolk, ATTN: Safety Ctr
1 Nav Oceanographic, DC, ATTN: Code 6251, Charts & Tech
1 Center of Naval Anal, ATTN: Doc Ctr
1 NavAirSysCom, ATTN: AIR-5313C
1 Nav BuMed, ATTN: 713
1 NavHelicopterSubSqua 2, FPO SF 96601
1 AFHRL (FT) Williams AFB
1 AFHRL (TT) Lowry AFB
1 AFHRL (AS) WPAFB, OH
2 AFHRL (DOJZ) Brooks AFB
1 AFHRL (DOJN) Lackland AFB
1 HQUSAF (INYSD)
1 HQUSAF (DPXXA)
1 AFVTG (RD) Randolph AFB
3 AMRL (HE) WPAFB, OH
2 AF Inst of Tech, WPAFB, OH, ATTN: ENE/SL
1 ATC (XPTD) Randolph AFB
1 USAF AeroMed Lib, Brooks AFB (SUL-4), ATTN: DOC SEC
1 AFOSR (NL), Arlington
1 AF Log Cmd, McClellan AFB, ATTN: ALC/DPCRB
1 Air Force Academy, CO, ATTN: Dept of Bel Scn
5 NavPers & Dev Ctr, San Diego
2 Navy Med Neuropsychiatric Rsch Unit, San Diego
1 Nav Electronic Lab, San Diego, ATTN: Res Lab
1 Nav TrngCen, San Diego, ATTN: Code 9000-Lib
1 NavPostGraSch, Monterey, ATTN: Code 55Aa
1 NavPostGraSch, Monterey, ATTN: Code 2124
1 NavTrngEquipCtr, Orlando, ATTN: Tech Lib
1 US Dept of Labor, DC, ATTN: Manpower Admin
1 US Dept of Justice, DC, ATTN: Drug Enforce Admin
1 Nat Bur of Standards, DC, ATTN: Computer Info Section
1 Nat Clearing House for MH-Info, Rockville
1 Denver Federal Ctr, Lakewood, ATTN: BLM
12 Defense Documentation Center
4 Dir Psych, Army Hq, Russell Ofcs, Canberra
1 Scientific Advsr, Mil Bd, Army Hq, Russell Ofcs, Canberra
1 Mil and Air Attache, Austrian Embassy
1 Centre de Recherche Des Facteurs, Humaine de la Defense Nationale, Brussels
2 Canadian Joint Staff Washington
1 C/Air Staff, Royal Canadian AF, ATTN: Pers Std Anal Br
3 Chief, Canadian Def Rsch Staff, ATTN: C/CRDS(W)
4 British Def Staff, British Embassy, Washington
1 Def & Civil Inst of Enviro Medicine, Canada
1 AIR CRESS, Kensington, ATTN: Info Sys Br
1 Militaerpsykologisk Tjeneste, Copenhagen
1 Military Attache, French Embassy, ATTN: Doc Sec
1 Medecin Chef, C.E.R.P.A.-Arsenal, Toulon/Naval France
1 Prin Scientific Off, Appl Hum Engr Rsch Div, Ministry of Defense, New Delhi
1 Pers Rsch Ofc Library, AKA, Israel Defense Forces
1 Ministeris van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands